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A Multi-Scalar Model to Identify the Causes of Decreased Vehicle Miles Traveled (VMT) in the United States

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Timothy John Garceau, PhD

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Decades of growth in overall and per capita vehicle miles traveled (VMT) led many to believe that the amount of driving would increase indefinitely. In the mid-2000's, driving levels in the U.S. and other developed countries peaked and began to decline. The phenomenon, referred to as "peak travel,", "peak car" and referred to here as "peak car travel," is occurring in places with very different layouts, densities and demographics, suggesting a fundamental shift in travel behavior. Simultaneously, after 70 years of concurrent growth, the extent to which VMT and Gross Domestic Product (GDP) are correlated is decreasing; showing that the relationship between the two may be changing. While factors such as population aging, a decline of young drivers, demand saturation and preference shifts all contribute to reduced VMT at one time or another or in one place or another, there is no clear explanation as to why peak car travel is occurring in such a widespread manner, on multiple scales, and in a diversity of places. This knowledge gap creates significant challenges for policymakers tasked with planning and building transportation systems that promote livable communities. Without a firm understanding of recent trends, it is nearly impossible to develop worthwhile travel predictions to guide decision-making processes. This dissertation works to fill this significant knowledge gap by analyzing peak car travel patterns at the state level, specifically as it relates to the relationship between driving levels, economic indicators and other factors known to affect travel behavior. Research findings provide a better understanding to transportation planners and policymakers regarding recent travel trends and will better inform them in making planning decisions that reflect current travel demands.

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Causes of Decreased Vehicle Miles Traveled (VMT) in the United States

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INTRODUCTION

VEHICLE MILES TRAVELED (VMT) AS AN INDICATOR

The amount of driving per person, as measured by Vehicle Miles Traveled (VMT) per capita in the United States (U.S.), is widely used as an indicator of transportation system performance and as an input to travel prediction models and funding disbursements (*1*). Beginning with the Clean Air Act Amendments (CAAA) of 1990 and reinforced by multiple federal transportation bills since that time, states have been required to submit estimates of VMT within their jurisdictions to the federal government (*1*). Since VMT estimates are used for a wide range of policy, funding and performance monitoring, the accuracy of these estimates is highly important (*1*). The Federal Highway Administration (FHWA) Highway Performance Monitoring System (HPMS) was established in 1978 to act as a national database of information regarding the extent, condition and use of highways in the U.S. (*2*) VMT estimates and other highway-related data are submitted to and managed by HPMS which has evolved to adapt to changes to the highway system, new transportation legislation and more advanced data gathering and management techniques (*2*).

The HPMS also acts as a clearinghouse for disseminating information regarding best practices of data gathering and estimation to state departments of transportation and regional transportation agencies. Improved practices and technologies of individual states are shared with other states through the HPMS (see: http://www.fhwa.dot.gov/policyinformation/hpms/statepractices.cfm) to promote best and consistent practices across the U.S. Despite this, however, states still have very different approaches to traffic counting on highways and roads within their jurisdictions and varying ways to estimate VMT as a result. FHWA and the Environmental Protection Agency (EPA) recommend using ground count-based programs to generate VMT estimates (*1*). The use of ground counts for highway travel is pretty consistent across the states however the focus of these counts is almost exclusively on federal- and state-funded highways and roadways (*1*). Though local and county roads (any roads not under the jurisdiction of the state) make up the majority of the road network, there is a strong variation from state to state in collection and estimation processes for local roads (*1*). While states have a target of performing traffic counts on major local roadways on a three-year rotating schedule, some states often struggle to meet even this timeline (*1*). This means that traffic counts for any particular local road are only taking place at a minimum of every third year but more realistically every fourth year or more. State estimates sent to the HPMS on the annual basis therefore involve a lot of extrapolation over time and interpolation over space with respect to local roads. As a result, annual estimates involve a high level of bias and therefore may not accurately represent current trends (*1*).

Despite these limitations, VMT estimates are still a primary indicator in planning and policymaking. Efforts to improve and standardize estimation practices provide promising opportunities to improve accuracy of VMT estimation. While the same estimation and bias issues affect VMT data as inputs into research modeling, VMT data are still widely used in transportation research as an indicator of travel behavior (*3*-*4*). To be consistent with the existing travel behavior research that this dissertation seeks to advance, VMT per capita is included as a core indicator in this dissertation and used as either a dependent or independent variable in most of the data modeling in this document. Many of the models and analyses in this dissertation also consider changes in VMT per capita over time. Despite the state-to-state variation in VMT estimates discussed earlier, it is reasonable to assume that estimation processes within a state have remained consistent over time except with respect to methodological improvements that would only serve to improve efficiency over time. As a result, using both a temporal and geographic approach to analyzing VMT per capita patterns, as is done in this dissertation, provides a more comprehensive and potentially more accurate approach to understanding driving patterns than an exclusively cross-sectional comparison of states would provide.

VMT PER CAPITA: GROWTH, PEAK & DECLINE

Since the invention of the automobile, and especially since World War II, car travel has reshaped the U.S. into a nation where automobiles are required in most places to meet daily needs (*5*). Increased driving resulted in increased congestion and, in order to sustain an automobile-oriented society that requires free-flowing roadways, policymakers and planners expanded road systems. Through what would later become known as the "cycle of induced travel" (*6-7*), each highway improvement, though temporarily relieving congestion, would ultimately generate new traffic demand and result in additional congestion (*8*). For over 60 years, the U.S. utilized a VMT-based approach to transportation policy which ultimately led to suburbanized land use patterns centered on highways and car travel (*9-10*). Other than during the energy crises in the 1970's and 1980's, driving levels in the U.S. continued record annual growth, leading to the expectation of and planning for continued record increases (*11-12*). In 2004, however, VMT per capita in the U.S. peaked and have declined in ensuing years (*13-14*). This phenomenon is referred to by some as "peak car" (*13,15*) or "peak travel" (*16*) is discussed as the focus of this dissertation under the name "peak car travel."

TAKING A STATEWIDE APPROACH

Using the statewide scale of analysis, peak car travel patterns and potential causes are analyzed to determine what factors are affecting travel behavior in what some have deemed to be a "new era of travel" comparable to revolutionary shifts in travel behavior that resulted from both the Neolithic and Industrial Revolutions (*17*). Prior to this dissertation, peak car travel research has focused primarily on national patterns in the U.S. or on similar peaking patterns across the developed world in places like Australia, France, Great Britain and Germany (*18-22*). Peak car travel researchers that have incorporated state level data (*11, 23-24*) have done so in a manner that considers a range of geographic scales. Their research has been at the cutting edge of the peak car travel phenomenon and in understanding the patterns at various scales. None of the existing research, however, has focused exclusively on the state level of analysis, particularly in considering evolving state level VMT per capita patterns over time.

OVERVIEW OF DISSERTATION

In terms of overall structure, this dissertation is organized into four distinct chapters; each intended to be a stand-alone journal article manuscript. Though separate, each chapter represents a complementary and cumulative advancement of research on VMT per capita, travel behavior and peak car travel.

The first chapter focuses on the use of VMT per capita as a key metric into transportation policy and planning. VMT estimates have been frequently used to assess the performance of transportation systems through the narrow lense of traffic flow and congestion. This chapter provides an example of how to utilize VMT per capita to assess transportation system performance in a more comprehensive manner. In arguing that transportation systems need to be evaluated for their ability to address the "three E's of sustainability" (environment, societal equity and economy), Zheng et al (*25*) developed a sustainability framework for performing such an evaluation. This research in the first dissertation chapter applies the Zheng et al metric to provide an example of how existing data can be utilized to more critically evaluate car-oriented transportation systems, especially in the context of sustainability goals.

The second chapter is a comprehensive literature review that focuses on the identification of the peak car travel phenomenon and discusses four potential causes of the phenomenon. As context for peak car travel, this chapter also discusses the historic trends of VMT per capita, the historic relationship between VMT per capita and Gross Domestic Product (GDP) per capita including an apparent recent decoupling of VMT per capita from GDP per capita, and a summary of the literature regarding factors known to affect travel behavior.

The third chapter takes a two-step approach to address notable gaps in state-level analysis with respect to peak car travel and to the decoupling of VMT per capita from GDP per capita. The first step focuses on driving levels for individual states from 1980 to 2011 to identify peak car travel patterns at the state level. The second step considers the VMT per capita and GDP per capita relationship at the state level the nature of this relationship from one state to another and also how the relationship is changing from one decade to another as well.

The fourth chapter focuses on the identifying the factors that relate to and are potentially causing peak car travel. Variables representing the broad array of known factors that impact travel behavior are included into a panel model using state-level data from 1990 to 2010. Taking a statewide approach to this discussion advances the established research which, prior to this dissertation, focused mainly on national and individual scales. Since the state level of governance in the U.S. is the scale where many transportation, land use and economic development decisions are made, it is imperative to understand how state effects serve to affect travel behavior and be contributing to or working against a state's transition into the peak car travel era.

REFERENCES

1. Fricker, J.D. and R.K. Kumapley. *Updating Procedures to Estimate and Forecast Vehicle-Miles Traveled*. Joint Transportation Research Program Project No: C-3617DDD, in cooperation with the Indiana Department of Transportation and the U.S. Department of Transportation (U.S. DOT) Federal Highway Administration (FHWA), 2002. http://docs.lib.purdue.edu/jtrp/214/. Accessed July 10, 2015.
2. U.S. DOT FHWA. *Highway Performance Monitoring System (HPMS*). 2014. http://www.fhwa.dot.gov/policyinformation/hpms.cfm. Accessed July 10, 2015.
3. Ecola, L., and M. Wachs of the RAND Corporation. *Exploring the Relationship between Travel Demand and Economic Growth*. FHWA, 2012. http://www.fhwa.dot.gov/policy/otps/pubs/vmt_gdp/index.cfm . Accessed May 7, 2013.
4. Schipper, L. Automobile use, fuel economy and CO2 emissions in industrialized countries: Encouraging trends through 2008? *Transport Policy,* Vol.18,No.2, 2011, pp.358–372.
5. Newman, P., and J. Kenworthy. *Sustainability and Cities: Overcoming Automobile Dependence*. Island Press, Washington, D.C., 1999.
6. Lee, D.B., L.A. Klein, and G. Camus. Induced traffic and induced demand. In *Transportation Research Record (TRR): Journal of the Transportation Research Board (TRB), No.1659,* TRB of the National Academies, Washington, D.C., 1999, pp.68-75.
7. Noland, R.B., and W.A. Cowart. Analysis of metropolitan highway capacity and the growth of vehicle miles of travel. *Transportation,* Vol.27, No.4, 2000, pp.363-390.
8. Goodwin, P.B. Empirical evidence on induced traffic. *Transportation,* Vol.23, No.1, 1996, pp.35-54.
9. Meyer, M.D. Transport planning for urban areas: A retrospective look and future prospects. *Journal of Advanced Transportation*, Vol.34, No.1, 2000, pp.143-171.
10. Marshall, A. *How Cities Work: Suburbs, Sprawl, and the Roads Not Taken*. University of Texas Press, Austin, TX, 2000.
11. Puentes, R. and A. Tomer. *The Road Less Traveled: An Analysis of Vehicle Miles Traveled Trends in the U.S.* Brookings Institute, Washington, D.C., 2008.
12. Liddle, B. Long-run relationship among transport demand, income, and gasoline price for the US. *Transportation Research Part D: Transport and Environment,* Vol.14,No.2, 2009, pp.73-82.
13. Newman, P., and J. Kenworthy. 'Peak Car Use': Understanding the Demise of Automobile Dependence. *World Transport, Policy & Practice,* Vol.17,No.2, 2011, pp.31-42.
14. Van Dender, K., and M. Clever. *New Recent Trends in Car Usage in Advanced Economies – Slower Growth Ahead? Discussion Paper No. 2013-09*, International Transport Forum, OECD, 2013. http://www.internationaltransportforum.org/jtrc/DiscussionPapers/jtrcpapers.html . Accessed May 15, 2013.
15. Goodwin, P., and K. Van Dender. 'Peak Car' – Themes and Issues. *Transport Reviews,* Vol.33, No.3, 2013, pp.243-254.

16. Millard-Ball, A., and L. Schipper. Are We Reaching Peak Travel? Trends in Passenger Transport in Eight Industrialized Countries. *Transport Reviews: A Transnational Transdisciplinary Journal*, Vol.31, No.3, 2011, pp.357-378.
17. Metz, D. Peak car and beyond: The fourth era of travel. *Transport Reviews,* Vol.33, No.3, 2013, pp.255-270.
18. Lucas, K., and Jones, P. *The Car in British Society: Trends and Challenges*. The RAC Foundation, London, UK, 2009.
19. Metz, D. Saturation of demand for daily travel. *Transport Reviews,* Vol.30, No.5, 2010, pp.659-674.
20. Stanley, J., and S. Barrett. *Moving People – Solutions for a Growing Australia*. Report for Australasian Railway Association, Bus Industry Confederation and International Association of Public Transport, 2010. http://apo.org.au/research/moving-people-solutions-growing-australia. Accessed July 25, 2013.
21. Kuhnimhof, T., M. Wirtz, and W. Manz. Decomposing Young Germans' Altered Car Use Patterns Lower Incomes, More Students, Decrease in Car Travel by Men, and More Multimodality. In *Transportation Research Record: Journal of the TRB, No.2023*, TRB of the National Academies, Washington, D.C., 2012, pp.64-71.
22. Madre, J. L., Y.D. Bussière, R. Collet, and I.T. Villareal. *Are we heading towards a reversal of the trend for ever-greater mobility?* Discussion Papers 2012-16, International Transport Forum, OECD Publishing, 2012. http://www.internationaltransportforum.org/jtrc/DiscussionPapers/DP201216.pdf. Accessed April 28, 2013.
23. Litman, T. *The mobility-productivity paradox: Exploring the negative relationships between mobility and economic productivity.* Victoria Transport Institute, 2014. http://www.vtpi.org/ITED_paradox.pdf. Accessed July 9, 2014.
24. Kooshian, C., and S. Winkelman. *Growing Wealthier: Smart Growth, Climate Change, and Prosperity*. Center for Clean Air Policy, 2011. http://www.growingwealthier.info/index.aspx. Accessed October 26, 2011.
25. Zheng, J., C. Atkinson-Palombo, C. McCahill, R. O'Hara, and N.W. Garrick. Quantifying the Economic Domain of Transportation Sustainability. *TRR: Journal of the TRB*, Vol. 2242, 2011, pp.19-28.

CHAPTER 1: EVALUATING SELECTED COSTS OF AUTOMOBILE-ORIENTED TRANSPORTATION SYSTEMS FROM A SUSTAINABILITY PERSPECTIVE

Published Work:
Garceau, T., C. Atkinson-Palombo, N. Garrick, J. Outlaw, J., C. McCahill, and H. Ahangari. Evaluating selected costs of automobile-oriented transportation systems from a sustainability perspective. *Research in Transportation Business & Management,* Vol.7, 2013, pp.43-53.

ABSTRACT

This paper uses an existing framework that encapsulates the concept of transportation sustainability to quantify and evaluate selected economic, social and environmental costs of automobile-oriented transportation systems as measured by rates of vehicle miles traveled (VMT) at the state-wide scale across the United States. States with higher percentages of commuting using private vehicles have higher rates of VMT per capita, higher carbon emissions, and pay more for transportation at the household level. Surprisingly, higher VMT per capita also corresponds to higher government spending on transportation, which likely reflects the expense of maintaining, repairing and often expanding road networks. States with higher automobile-dependency also incurred higher social costs as measured by automobile-related fatalities. States with three times the VMT per capita than other places incurred five times as many fatalities showing that fatality rates are not simply a direct function of the amount of VMT occurring. Together, these metrics provide compelling evidence for the need to think about the impacts of VMT in a more holistic manner. These data can inform the global debate about the costs of VMT and provide guidance to those in transportation business and management to formulate cost-benefit analyses that are rooted in a transportation sustainability perspective.

INTRODUCTION

Growing concern about a variety of transportation-related issues such as fossil fuel dependence, the future trajectory of gasoline prices in a post-peak-oil environment, and the effect of greenhouse gas (GHG) emissions on global climate have motivated a shift in many developed countries towards conceptualizing transportation from a sustainability perspective (*1-3*). In the United States, in particular, this change comes after more than fifty years of transportation policy focused almost exclusively on automobile travel (*4*). Freeway expansion twinned with the mass production of the automobile facilitated the suburbanization of people, jobs and amenities to produce what some numerous critics have described as sprawl (*5*). Despite being notoriously difficult to define and measure (*6*), the concept of sprawl has been linked with a wide variety of negative externalities (*7*). A large body of evidence about various negative impacts of sprawl has supported the adoption of public policies to reduce it (*8-13*). Environmental concerns include the loss of farmland and open space, air and water pollution generated by vehicle emissions, and, more recently, greenhouse gas (GHG) emissions such as carbon dioxide that are widely agreed to be responsible for global climate change (*14-16*). On the economic front, many have recognized the stark reality that the United States' economic system is structurally dependent on a commodity that it needs to import, whose price is set by forces of supply and demand at the global scale, and whose supply may be dwindling (*17-20*). Another prominent concern of local and regional governments is the cost of maintaining (and sometimes replacing) infrastructure built during the era of freeway construction and expanded thereafter (*21-22*). Others are concerned about the human cost of automobile dependency, motivated by the fact that motor vehicle crashes are the leading cause of death among those aged 5-34 in the United States (*23-24)*.

One of the most challenging aspects of automobile-oriented transportation systems is the creation of a vicious cycle between land-use and transportation (*25-27*). The Congestion Index, produced by the Texas Transportation Institution (TTI), is one of the most prominent metrics used to evaluate the performance of transportation systems. This indicator, which compares the time taken for a journey in peak versus off-peak hours, has been used to monetize the amount of time spent in traffic, and provided support for freeway expansion. Despite its popularity, this metric is rather limited because it captures only one aspect of a transportation system—the time spent in traffic (*28*). New freeways tend to induce demand which produces rather than relieves congestion (*29*). The resultant expansion of the transportation network has enabled development to take place at more distant locations which has resulted in people having to drive more to access the same places. In the United States, drivers accumulate approximately three billion miles each year—a twelve-fold increase from 1945—accruing more of what Kooshian and Winkelman (*30*) have described as "empty miles" (*31*).

Fundamentally rethinking the objective of transportation policy in the United States so that it prioritizes the creation of accessibility for people rather than providing mobility for vehicles is not new. Well before the national freeway system expanded across the United States, social commentators such as Jane Jacobs (*32*) and Lewis Mumford (*33*) raised concerns about the damage that freeway construction could inflict on the fabric of cities. Their ideas have been embraced by proponents of new urbanism who promote the creation and restoration of diverse, walkable, compact, vibrant, mixed-use communities composed of the same components as conventional development, but assembled in a more integrated fashion, in the form of complete communities. These contain housing, work places, shops, entertainment, schools, parks, and civic facilities essential to the daily lives of the residents, located within easy walking distance of each other. New Urbanists also promote the increased use of trains and light rail rather than the creation of more highways and roads (*34-35*). The interrelationship between transportation and land-use is also a prominent theme in many smart growth and sustainable development policies that have been adopted at regional, state-wide, and local scales (*9*, *11, 37*). While many subtle and not so subtle differences exist between these emerging planning paradigms (*38*), all of these approaches rest upon the fundamental idea that transportation needs to be considered in a broad context instead of the rather compartmentalized approaches to public policy where one agency deals with transportation policies, and other agencies deal with impacts of that transportation policy, such as air and water pollution.

The federal government in the United States has recently acknowledged that policies relating to transportation, housing, and the environment need to be integrated across multiple government agencies

(*39*). The emphasis on Sustainable Communities by the US Department of Transportation (DOT), Housing and Urban Development (HUD) and Environmental Protection Agency (EPA) that focuses on issues of transportation and sustainability is one sign of the first tentative steps being taken to reframe transportation in a broader context. Some have pointed out that the concept of sustainability, as it is current posed, is still somewhat nebulous (*40-43*). While true, the fact remains that this discussion of sustainability signals an important change in focus at the federal level.

In response to this changing discourse, researchers have expanded efforts to develop approaches to measure the broader impacts of transportation that are implied by the terms sustainability and livability (*44-48*). In this paper, the framework for transportation sustainability created by Zheng et al. (*48*) is utilized as the theoretical foundation for quantifying and comparing three considerations of costs associated with VMT (one for each of the three domains of sustainability—economy, society, and environment) using data at the state-wide scale across the United States. It is important to mention that although methods do exist to express impacts such as deaths associated with traffic fatalities and GHG emissions in monetary terms, data in this paper are presented in their original units because these are compelling reflections of VMT impacts in their own right. In addition, it is also pertinent to point out that the indicators used in this paper are not the only possible indicators for each domain. Rather, there are many other economic, social and environmental impacts that could be measured and will hopefully be incorporated into future research.

The data highlight the very important point that, despite resistance to target VMT for reductions (*49*), VMT incurs costs in all three domains of sustainability. Whether or not these costs are sufficiently high to generate broad-based support for investment in alternative policies is for the public to decide. The goal of this paper is to present the data so that it can be used in the public debate about the costs associated with transportation policies that support further expansion, or conversely, contraction of VMT. The core questions to be answered by this paper are: how do VMT and level of automobile-dependence interrelate, what are some of the costs associated with VMT, and how do they vary across states with different levels of VMT/automobility? While VMT growth has tapered off in the United States, the findings may be of use to transportation policy-makers elsewhere in the world, especially in those places where VMT is expanding.

The remainder of the paper comprises three additional sections containing a literature review which provides the foundation for discussing the role of VMT in the transportation sustainability debate; the data, including analysis and results; and a discussion of our findings that focuses on their implications for managerial practice and contributions to the scholarly debate about transportation sustainability.

LITERATURE REVIEW

In this review, the various strands of literature are woven together to provide a very brief narrative of how transportation policy has emerged and evolved from the beginning of the automobile era until the present day. In the interest of space, a broad picture is painted that will hopefully provide a concise background of how and why transportation sustainability has become prominent in contemporary policy debates, and why the amount of VMT and its costs are foundational to these debates.

The Automobile Era and Trajectory of VMT

The automobile era in the United States was enabled by the combination of mass production of the automobile, the Servicemen's Readjustment Act of 1944 that provided low interest, zero down payment home loans for servicemen returning from WWII, the Housing Act of 1949 that enabled the Federal Government to spend $13.5 billion on urban redevelopment and slum clearance between 1953 and 1986, and the 1956 Federal Highways Act that launched the construction of a national interstate network comprised of 47,182 miles of roadways as of 2010 (*50*). Since 1945, the vehicle ownership rate in the United States has risen steadily from 222 per 1,000 people to 828 per 1,000 people, as of 2009 (*51*). A fleet of approximately 240 million vehicles in the United States (as of 2010) cover almost three trillion miles a year, a quarter of which takes place on the interstate system (*52*). From 1945, VMT per capita has more than quadrupled from 1,650 to just below 10,000 as of 2010, outstripping the growth in vehicle ownership rates. The rate of growth of VMT per capita has varied over time. An overall upwards trend has been punctuated with sharp periods of decline corresponding to recessions, particularly those associated with the first and second oil shocks in 1973-74 and 1979-80 (see Figure 1). Growth rates have declined over the decades from an average of 4.3% from 1945 through the end of the seventies, to 2.3% in the eighties, 1.7% in the nineties, and barely any growth during the 2000s (0.1% from 2000 through 2010). Some suggest that this tapering off in VMT growth indicates that a peak level of car mobility may have been achieved (*53*). Other explanations include higher gasoline prices, the global recession of 2007, and the aging of the population (*54*-*55*). Evidence is also emerging that people's attitudes towards car ownership, driving and suburban living may be changing, and that the variety of anti-sprawl measures adopted in the United States over the past two decades may be taking effect (*56*-*58*).

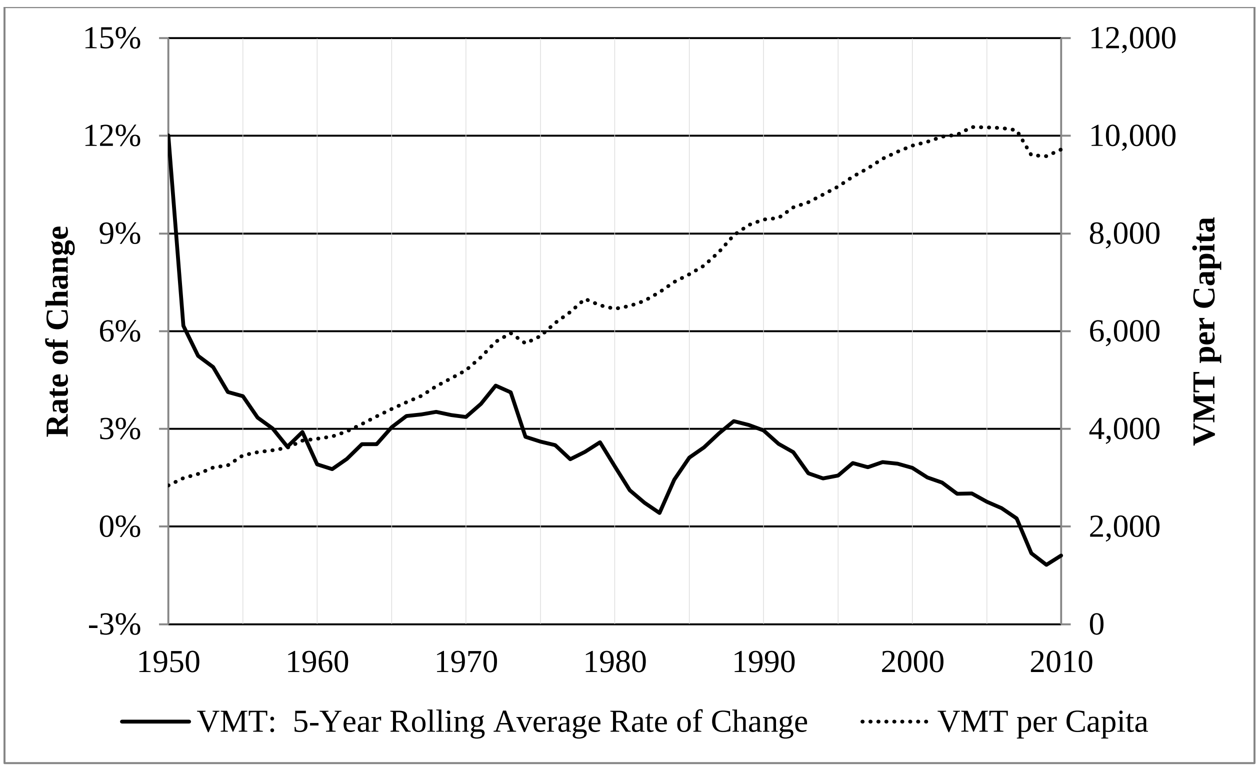

FIGURE 1: Vehicle Miles Traveled (VMT) per capita and the 5-Year Rolling Average Rate of Change for VMT per capita in the United States, 1950-2010

During this era, transportation policy has been carried out in a "predict and provide fashion" and dominated by the need to relieve congestion (*29,59-60*). The Urban Mobility Report (*61*), produced by the Texas Transportation Institute (TTI), measures and ranks congestion-related travel times for the largest metro areas. The congestion index, computed as a ratio of the peak and non-peak travel times, has been the standard measure of urban transportation systems for quite some time. CEOs for Cities issued a report calling attention to the fact that the TTI's tools are not sufficient (*28*). They point out that the focus should not be on how much delay people experience but rather on how much time they actually spend commuting. For instance, they point out that residents of sprawling metro areas, regardless of their level of congestion, may actually spend more hours in the car than people in less sprawling places even when they are more congested. The CEOs for Cities report provides an improvement to methodology and accuracy but may not go far enough as it still focuses on mobility as the measure of a transportation system. For decades, researchers have called attention to the insufficiency of focusing on volume-to-capacity measurements of highway systems. In the 1970's, Dajani and Gilbert (*62*) pointed out the need to develop measures of performance for transit modes as well as freeways. Despite this acknowledgement, the transition towards incorporating other transportation modes has been slow. In the meantime, the "predict and provide" approach has created a vicious cycle between transportation and land-use and contributed to increases in VMT.

Environmental Externalities of Transportation

One of the most prominent externalities associated with increased freeway expansion and increased VMT has been their environmental impact. Transportation systems cause a wide variety of degradations to ecosystems by bifurcating natural habitats, altering and contaminating drainage systems, and generating air pollution that has impacts hundreds of miles away (*63*). Automobiles are a leading source of pollutants including carbon dioxide (CO_2), methane, nitrous oxide and hydrofluorocarbons (*21,63*). Ozone produced by the interaction of vehicle emissions with the atmosphere has been found to make entire forests susceptible to decline (*64*) and negatively impact agricultural production. Murphy et al.

(*65*) found that, by reducing or eliminating ozone emissions from motor vehicles, the agricultural sector could increase productivity by up to $6.1 billion annually. With respect to human health, ozone and particulate matter can cause respiratory issues and negatively affect lung functions (*66*) and even increase mortality (*67*). In order to minimize the impact, the federal government has long enforced the Corporate Average Fuel Economy and emissions standards (*68-69*).

Many of these issues are critical to address at a local level, but there is also growing concern regarding global impacts including climate change, attributed in large part to the emission of GHGs such as CO_2. The U.S. transportation sector accounts for roughly one-third of nationwide CO_2 emissions and 10 percent of worldwide greenhouse gas emissions (*70-72*). Tailpipe emissions from combustion engines account for 28-29% of CO_2 emitted in the country (*63,73*). Life-cycle costs of vehicle production, infrastructure construction and maintenance and extraction and refining of fuels account for another 8% of national GHG emissions (*63*). From 1990 to 2006, transportation GHG emissions increased 27% and comprised half of the new U.S. emissions during that period (*63*). Since automobile travel is higher in low density, car-dependent rural and suburban areas (*74*), automobile-related GHG emissions are higher in those areas as well (*75*).

The issue of transportation-related CO_2 emissions is one that motivated the development of the U.S. DOT, U.S. EPA, and U.S. HUD's Partnership for Sustainable Communities *(39,76*) and it has been the focus of reports by the U.S. EPA (*72*) and the Urban Land Institute (*77*). These sources as well as others (*21*) indicate that reductions in automobile use are necessary for reducing emissions, in combination with the adoption of fuels with lower carbon content and technological advances that improve vehicle efficiency. Malaczynski (*78*) similarly found that, to meet emissions reductions targets, a simultaneous increase of efficiency and reduction of VMT is necessary. Traffic congestion and the resulting highway system inefficiencies also generate additional unnecessary emissions however, Nagurney et al (*79*) found that reducing congestion to make highways more efficient will actually induce travel and generate more emissions than in congested conditions.

With so much of the developed landscape and urban systems built around the automobile, reducing emissions through deliberate VMT-reductions has been met with resistance. Pisarski (*80*), in a reaction to the Moving Cooler report (*81*), challenges the notion that getting people out of cars and into other modes will actually reduce emissions and provide overall benefits. He points out that the report did not incorporate the expected increased travel times that will result from shifting modes from autos to transit nor did it include the higher emissions of transit vehicles, particularly when operating at low capacity. Moore et al. (*49*) argue that technological advancements will be the key to reducing emissions, not changing travel behaviors. They point to federal efficiency standards and system optimization (i.e. reduced congestion through traffic signal optimization and other means) as being the preferred and most effective means for reducing GHG emissions.

It is widely assumed that adopting policies to address the environmental impacts of GHG's will incur costs. McKinsey & Co. (*82*) found that significant progress can be made but it is with an estimated cost of $50 per ton of CO2. Stern (*83*) calculated that it would take 1% of the global gross domestic product (GDP) to avoid the worst effects of global warming but that failing to make this investment could cost up to 20% of the global GDP in damages. Failing to take action would have costly impacts to transportation systems resulting from increased storm frequency and strength and raised sea levels which could cutoff parts of coastal transportation networks (*84-85*). Geographically, the damaged areas may be localized but the network effects would be multiplicative. To avoid getting to that point, Deakin (*86*), citing the TRB Special Report 251 (*87*), states that significant GHG emissions reductions could be made through travel demand management, land-use planning changes, increasing new vehicle fuel efficiency and increasing fuel prices. Nevertheless, the general idea that changes will incur costs is the primary basis upon which resistance to them is based.

Economic Considerations of Transportation

While automobile travel has increased over the last several decades, so too have household incomes. On a percentage basis, however, the proportion of household budgets spent on transportation has increased.

Jacobs and Shipp (*88*) found that since the Monthly Labor Review started publication, transportation spending at the household level has increased significantly. In 1950, an average family spent five times as much on food as they did on their car but by 1987, families were already spending the same amount to move their families around by car as they did to feed them (*88*). While costs per mile to drive decreased from $0.59 in 1984 to $0.34 in 2001, increases in VMT have offset the cost improvements and increased household transportation costs overall (*89*). When you factor in that costs per household are increasing while household occupancies are declining, the cost per person increase is even greater (*89*). Kooshian & Winkelman (*30*) found that VMT increased 71% for the average household over a 40-year span but that household income for the lower three quintiles did not keep pace with increased driving, increasing only 18% during that time period. Ewing et al. (*77*, citing Pisarski, *90*) looked at the causes of VMT growth from 1983 to 1990 and found that increased travel distances accounted for 35% of new VMT (*77*). In other words, 35% of new VMT resulted from users needing to drive further to access the same goods, reflecting a decrease in efficiency over time. Despite increased costs associated with automobile travel, the amount of driving has still increased because studies have found that driving is not impacted by marginal price fluctuation (*73,91*). Rather, automobile ownership, registration, insurance and licensing all amount to user investments in the automobile as the mode of choice such that, if available, the household car is used for 96% of *motorized* trips (*92*). Under equal conditions, it would be expected that increased costs to operate a vehicle would reduce auto travel or create a shift to other modes. Since 1998, however, gas prices increased 222% and, rather than reducing car travel, VMT actually increased 16.8% during the same time period (*93*). With up-front user investments in the automobile, modal shifts to reduce VMT may not be as easy a solution**.** To get a grasp of indirect costs associated with automobile use, Delucchi (*94*) analyzed travel time, consequences of accidents (e.g. pain, death, lost productivity), personal time spent fueling and repairing personal cars as well as time spent buying, selling and disposing of cars (not counting commercial dealers). The author determined that these costs total up to $878.3 billion per year to overall users.

Several studies have tried to estimate the "true costs" of transportation (*95-98*). Litman (*97*) pointed out that costing estimates often neglect to include lost opportunity costs associated with land committed to transportation and, if including land-associated costs, may only look at cost to acquire land through eminent domain, for example. Delucchi & Murphy (*99*) took a look at public costs associated with motor-vehicle infrastructure and services at federal, state and local levels. They found that total government spending annually was over $118 billion on highways alone, over $88 billion on police enforcement related to automobiles, nearly $40 billion on legal and judicial actions, over $63 billion and $27 billion on corrections and fire, respectively. This represents nearly $340 billion spent annually in constructing, maintaining, servicing and supporting an automobile-based transportation system. The costs are so great that McCann (*100*) found that households in sprawling metropolitan areas end up spending more on their transportation expenses and that areas with fewer modal options are more expensive to users.

Social Burdens of Transportation

As household transportation costs have continued to increase, so too have some of the other negative externalities of automobile dependence. The most dramatic cost of increased travel is an increase in automobile accident fatalities. The rate of fatalities has been tied to economic conditions and its associated rates of increasing VMT. Internationally, Bishai et al. (*101*) found that GDP increases in poorer countries resulted in increased automobile-related fatalities but that, once countries were on the wealthier side, fatalities decreased. Despite lower fatalities in wealthier countries, the number of crashes and injuries still increased with GDP increases; most likely as a result of better medical care after the accident (*101-102*). Geographic conditions, specifically the density of street intersections and density of traffic itself, are also found to impact the severity of crashes. Marshall & Garrick (*103*) found that the highest risk of fatal and severe crashes occur in areas with lower intersection densities and sparser street networks (i.e. more suburban and rural locations) than in denser areas. Edlin & Karaca-Mandic (*104*) had similar findings where, although accident rates were higher in areas with more traffic and congestion, the severity of accidents was worse in less traffic dense areas. Despite this, they found that traffic dense states had higher insurance costs of up to $3,239 per driver (*104*). In the year 2000 alone, costs associated with injury, property damage, lost productivity and other factors amounts to $433 billion or 15.8 cents per VMT (*21*).

Anti-Sprawl Policies

Mounting evidence of the damaging effects of automobile-oriented outwards expansion—or sprawl—has led to the adoption of many policies aimed at combating sprawl at the local, regional, federal, and national scales in the United States (*37*). Contemporary planning paradigms such as new urbanism, smart growth, the sustainable cities movement, and the ecological cities movement have suggested a variety of ways in which to counter sprawl. Policy tools include adopting urban growth boundaries such as the one delineated for Portland, Oregon (*105*), clustering development onto the spine of transit using light rail transit and transit-oriented development (*106*), and creating incentives for developers to undertake infill rather than greenfield development (*107*). What has become increasingly evident from working through many of these approaches is that transportation policy is a cross-cutting issue that cannot be carried out in isolation from the other policy areas that it affects.

Transportation Sustainability

Growing awareness of the need to consider transportation policy in a more holistic manner has led to increased focus on the concept of transportation sustainability (*108*; also see Zheng et al., *48* and the references therein). While a sustainable transportation system has been defined in various ways, the following description by the Centre for Sustainable Transportation (*44*) has proven popular:

- *Allows the basic access needs of individuals and society to be met safely and in a manner consistent with human and ecosystem health, with equity within and between generations;*
- *Is affordable, operates efficiently, offers choice of transport mode and supports a vibrant economy; and*

- *Limits emissions and waste within the planet's ability to absorb them, minimizes consumption of non renewable resources limits consumption of renewable resources to the sustainable yield levels, reuses and recycles components, and minimizes the use of land and the production of noise.*

Zheng et al. (*48*) propose that transportation systems need to be evaluated for their ability to address the traditional "three E's" of sustainability: Environment, Society and Economy. They develop a sustainability framework where each of these three domains has their own sets of goals for a successful transportation system. Each goal is then represented by measurable indicators and variables. The Zheng et al. (*48*) framework is the basis for this paper. For each of the three domains, a sample indicator has been identified and evaluated with a focus on automobile travel, specifically the impacts of VMT on household budgets, on fatalities and on GHG emissions. In doing so, this paper presents an alternative way of quantifying and evaluating some of the costs of VMT.

RESEARCH QUESTIONS

The core questions to be answered by this research are: how do VMT and level of automobile-dependence interrelate, what are some of the costs associated with VMT, and how do they vary across states with different levels of VMT/automobility?

DATA

Various data at the state-wide scale were compiled for 2009 (see Table 1). Washington, D.C. is also included and treated as the equivalent of a state for the analyses. Alaska, due to variations in infrastructure, geography, fuel use, prevalence of air travel and government spending in comparison to the other states, has been omitted from our dataset. The data analysis began with an evaluation of the relationship between VMT and commuting behavior, and continued with analyses of the relationship between VMT and proxies for economic, social, and environmental costs represented by household and government spending on transportation, automobile-related fatalities, and carbon dioxide emissions respectively.

TABLE 1: Data Sources

Data*	Source	Date	Sample Size
Vehicle Miles Traveled (VMT)	U.S. Department of Transportation (DOT), Federal Highway Administration (FHWA), 2012. Highway Statistics 2009, Table VM-202: Annual Vehicle-Miles of Travel, 1980-2009. Retrieved 31 May 2012 from: <http://www.fhwa.dot.gov/policyinformation/statistics/2009/vm202.cfm>.	2009	50
Population	U.S. Department of Commerce, U.S. Census Bureau, 2009b. Table 1, Annual Estimates of the Population for the United States, Regions, States and Puerto Rico: April 1, 2000 to July 1, 2009. Accessed 16 October 2011 from: <http://www.census.gov/popest/data/state/totals/2009/index.html>.	2009	50
Commuting Behavior (the percentage of commuters using private vehicles to get to work)	U.S. Department of Commerce, U.S. Census Bureau, 2009a. American Community Survey 1-Year Estimates: Table S0802, Means of Transportation to Work by Selected Characteristics. Accessed 7 July 2012 from: <http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml>.	2009	50
Household spending on transportation (as a percent of household income)	Zheng, J., Atkinson-Palombo, C., McCahill, C., O'Hara, R., Garrick, N.W., 2011. Quantifying the Economic Domain of Transportation Sustainability. Transportation Research Record: Journal of the Transportation Research Board 2242, 19-28.	2007	50
Government spending on fuel (as percent of GDP)	Zheng et al., 2011 (*48*)	2009	50
Government spending on transportation (state and local)	USDOT, Bureau of Transportation Statistics, Research & Innovative Technology Administration, 2010. State Transportation Statistics 2010: Table 6-8 Transportation Expenditure by State Governments, 2008. Retrieved 24 May 2012 from: <http://www.bts.gov/publications/state_transportation_statistics/ state_transportation_statistics_2010/index.html>.	2008	50
Automobile-related fatalities per 100,000 people	USDOT, FHWA, 2011. Highway Statistics 2009, Table FI-220: Persons Fatally Injured in Motor Vehicle Crashes, 1980-2009. Retrieved 16 October 2011 from: <http://www.fhwa.dot.gov/policyinformation/statistics/2009/fi220.cfm>.	2009	50
Carbon dioxide emissions	U.S. Department of Energy, Energy Information Administration, 2010. State Energy Data System: 2010 Estimates by Energy Source: Petroleum & Fuel Ethanol. Retrieved 17 May 2012 from: <http://www.eia.gov/state/seds/seds-data-fuel-prev.cfm>.	2010	50
Carbon dioxide emissions	U.S. Environmental Protection Agency (EPA), 2012. U.S Greenhouse Gas Inventory Report. Accessed 17 May 2012 from: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.	2010	50

*All data state-level

ANALYSIS AND RESULTS

VMT and Commuting Behavior

To address the question of how VMT and the level of auto-dependence interrelate, commuting behaviors were analyzed. Specifically, the percent of commuters using private vehicles (single-occupant and carpooling) to get to work is used as an indicator of auto-dependency. Commuting data is then compared to VMT per capita figures to determine the relationship between states with higher percentages of private automobile commuters and states with high VMT rates.

The percentage of people commuting to work by private vehicle for each state regressed against VMT per capita at the statewide level was statistically significant at the 0.000 level, with an adjusted R^2 of 0.30. There exists a positive relationship between the two variables such that higher VMT per capita associates with states where people are more dependent on the automobile for their commute (see Figure 2). Examples of more auto-dependent states are Alabama (13,018 VMT per capita, 94.7% commuting in private vehicles), Indiana (11,930, 92.2%), Mississippi (13,695, 94.3%) and Oklahoma (12,747, 92.9%). Conversely, lower VMT per capita associates with states that have lower percentages of private vehicle commuting. These include Illinois (8,199, 82.4%), Massachusetts (8,313, 80.1%), Oregon (8,880, 82.4%) and Washington State (8,466, 83.4%).

The adjusted R^2 may be lower due to the two prominent outliers at the lower end of the VMT range (Washington, D.C: 6,017, 43.1%;. and New York: 6,831, 61.4%) and one at the upper end (Wyoming: 17,580, 88.1%), and also probably influenced by the fact that data are aggregated across entire states.

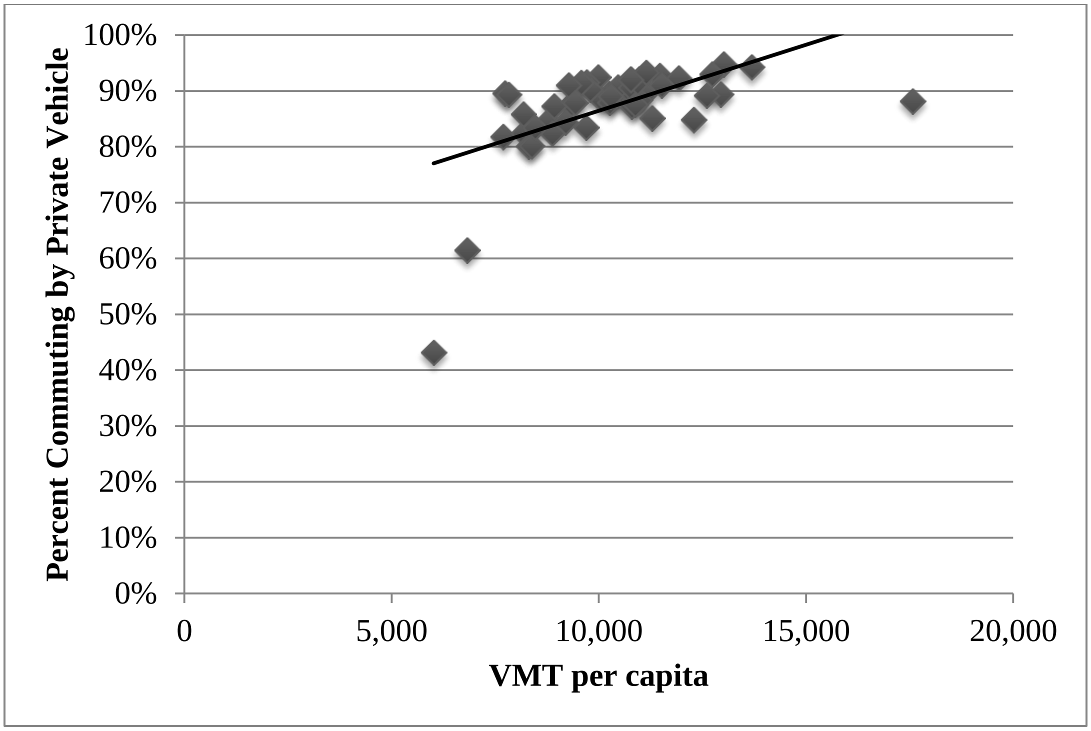

FIGURE 2: Relationship between VMT per capita and the percentage of commuters driving to work, 2009

Economic Costs

This section contains the analysis of three relationships: (a) per capita government spending on transportation (state and local combined); (b) spending on fuel as percent of gross domestic product (GDP); and (c) household transportation spending as a percent of income.

Government transportation expenditures for each state include both municipal level and state level spending on transportation (highways and transit). This includes project development, construction, maintenance, operations and other associated costs. As shown in Figure 3, there is a positive relationship between government spending on transportation and VMT levels ($R^2 = 0.26$) such that states with higher automobile travel are generally also those states which pay more to build, maintain and operate their transportation systems. Vermont (12,297 VMT per capita, $711 per capita), North Dakota (12,606, $960) and South Dakota (11,825, $827) are ranked in the top 10 in both highest VMT per capita and highest government expenditure on transportation.

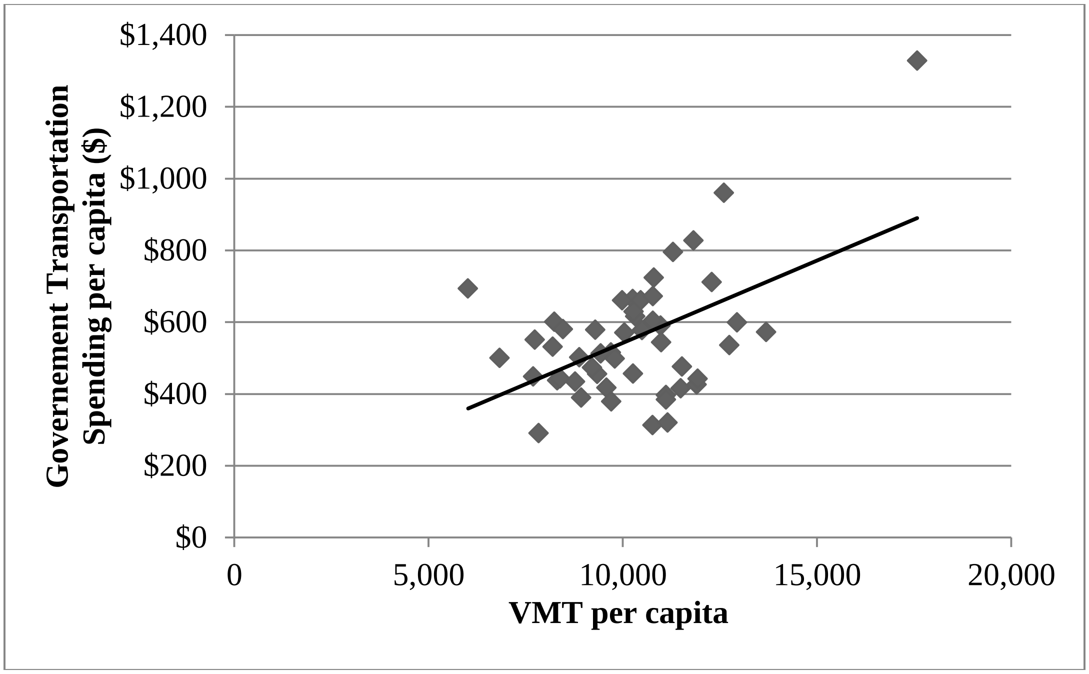

FIGURE 3: Relationship between VMT per capita and government transportation spending per capita (in dollars), 2009

Wyoming, with the highest VMT per capita (17,580) and highest transportation spending ($1,328), is an outlier resulting from having the lowest population density (5.8 people per square mile) of the states included in our analysis (*109*). Wyoming's low density forces residents to drive long distances (and accumulate miles in the process) in order to access goods and services that would typically be closer for residents in other states. In addition, the large geographic area is crisscrossed by highways and roads that are expensive to maintain and, with a low population, the cost per capita increases dramatically.

Washington, D.C. is an anomaly with the lowest VMT per capita (6,017) but the seventh highest transportation spending by the government ($694 per capita). These figures could be disproportionately high because the Washington Metropolitan Area Transit Authority ("Metro") actually serves portions of two other states (Maryland and Virginia) and the costs associated with running the Metro may actually be assigned to Washington, D.C. within the dataset.

Government spending on fuel provides an even stronger depiction of the high costs of VMT. Using the percent of state GDP spent on fuel, it was found that states with higher fuel expenditures also tend to be the states with higher VMT per capita (See Figure 4; $R^2 = 0.52$). Wyoming (17,580 VMT per capita, 4.2% of GDP spent on fuel), Mississippi (13,695, 4.8%), and Oklahoma (12,747, 3.8%) are all in the top 5 highest states in VMT per capita and government expenditures on fuel. On the lower end of the rankings, six states of the ten with the lowest VMT per capita are also in the lowest ten states in terms of fuel expenditures (Massachusetts, Pennsylvania, Illinois, Rhode Island, New York and Washington, D.C.; ranging from 6,017 to 8,313 VMT per capita and 0.22% to 2.26% of GDP spend on fuel). While fuel spending is a direct financial issue for states, the susceptibility to fuel price fluctuations is an indirect, though possibly more drastic issue as increasing fuel costs could hinder economic activity in states that are not prepared to transition to alternative modes or fuels.

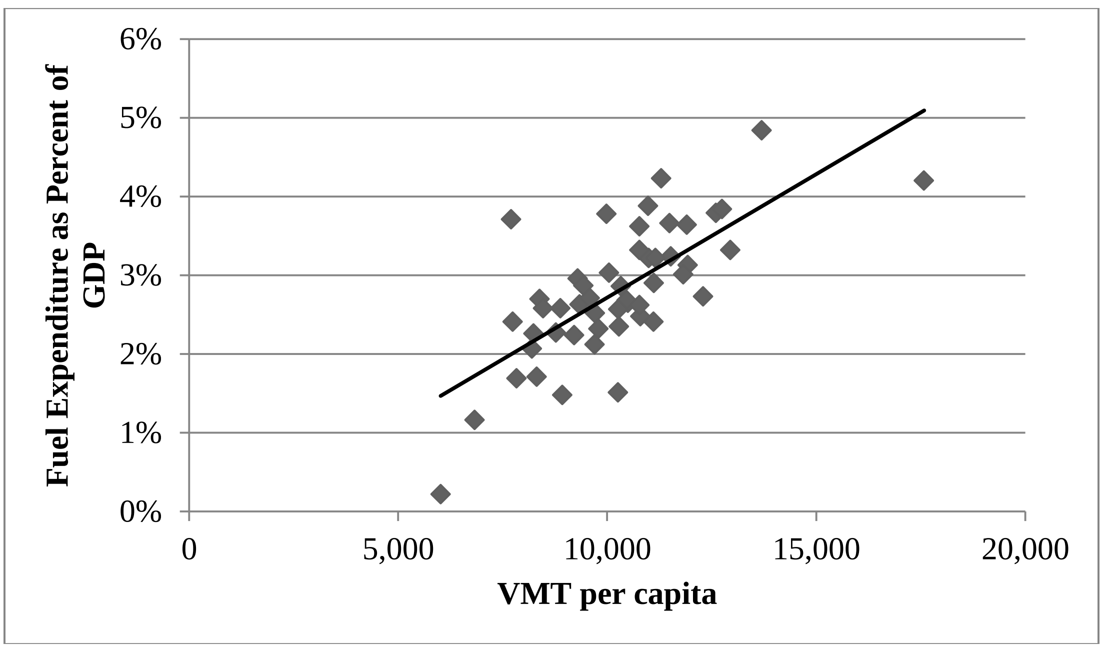

FIGURE 5: Relationship between VMT per capita and fuel expenditures (as percent of GDP), 2009

Of the three economic variables considered, the best indicator of the economic costs associated with VMT is the percent of household income spent on transportation. Data from Zheng et al. (*48*) regarding household expenditures includes, but is not limited to, the costs of vehicle purchases, vehicle operation and maintenance, insurance, fuel and public transit fees. As shown in Figure 5, the percent of income spent on transportation is significantly associated with VMT per capita ($R^2 = 0.64$). Household spending ranges from approximately 16% to 41%, depending on the state and the rate of VMT. On the higher end, households in Mississippi, Wyoming, New Mexico, Oklahoma and Alabama spend over a third (> 33%) of their incomes in generating five of the highest VMT per capita rates. By comparison, the average U.S. household spends 28% on transportation while residents in six states spend 21% or less of their incomes on transportation (Connecticut, Hawaii, Maryland, Massachusetts, New Jersey, New York and Washington, D.C.). These findings suggest that while higher levels of automobile use are associated with greater levels of spending, they are not necessarily linked to greater levels of affluence. This means that, at the household level, the costs of owning and driving vehicles hits those with lower incomes disproportionately hard.

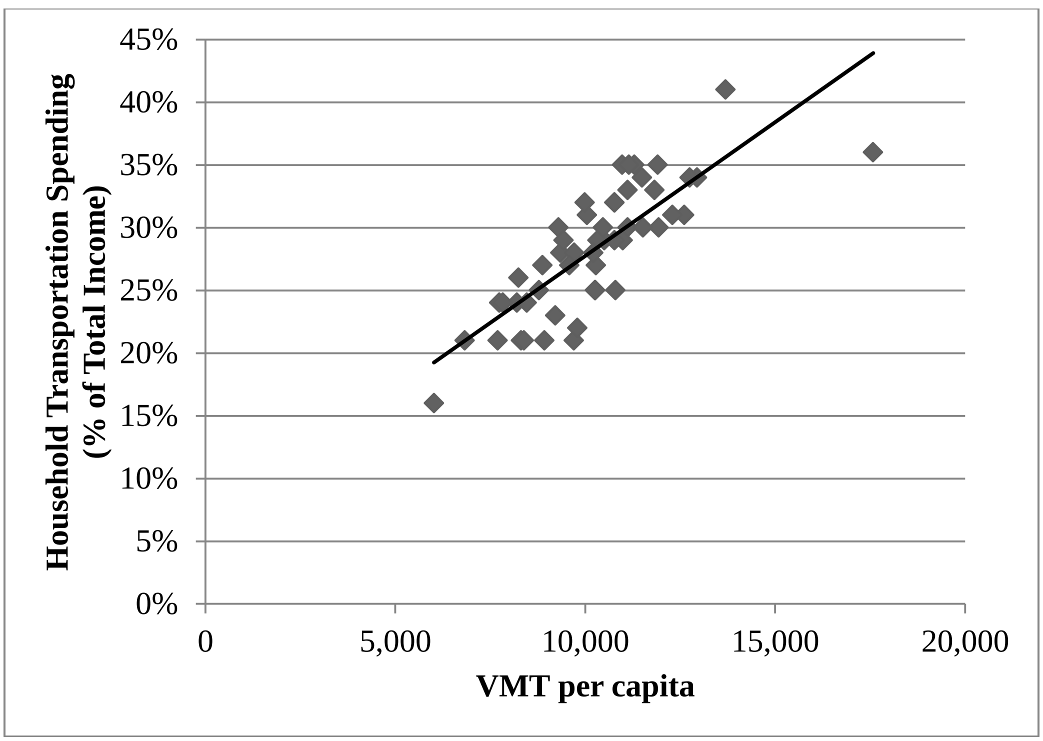

FIGURE 5: Relationship between VMT per capita and household transportation spending (as percent of total household income), 2009

Social Costs

While there are many social costs associated with transportation, including inequities and health and safety impacts, the authors of this study relied on data regarding the number of automobile-related fatalities as an indicator of social impacts for each state. In general, social costs are largely qualitative and thus more difficult to measure.

As shown in Figure 6, the number of fatalities per capita in each state is positively associated with VMT per capita ($R^2 = 0.65$). Of the 22 states with less than 10,000 VMT per capita, 19 states have 10 or fewer fatalities per 100,000 people. The other three states have approximately 12 fatalities (Arizona and Texas) and 18 fatalities (Louisiana). Massachusetts and Washington, D.C. have the lowest fatality rates with 5 per 100,000 people while Connecticut and New York have 6 fatalities per 100,000 people. These states range from 6,000 to 8,000 VMT per capita.

By comparison, the amount of VMT per capita is twice as high in the highest driving states (e.g. Mississippi, 13,695; Alabama 13,018; Vermont, 12,297 and several others) than the lowest driving states. The result of increased VMT rates on fatalities, however, is three- to four-times higher than that of lower VMT states like Massachusetts and Connecticut. Oklahoma residents drive 12,747 VMT per capita which results in 20 fatalities per 100,000 people; 400% higher than Massachusetts and Washington, D.C. with only a 200% increase in VMT. This suggests that states with higher VMT rates have not only a greater number of traffic deaths, but that the risk of death per VMT is even higher.

As in previous analyses, Wyoming is once again an outlier due to the 17,580 VMT per capita accumulated annually. These miles result in 24.6 fatalities per 100,000 people each year; a five-fold increase over the states with the lowest fatality rates! Mississippi, despite nearly 4,000 less VMT per capita than Wyoming, has a fatality rate that rivals Wyoming at 23.7 traffic deaths per 100,000 people.

Assessments that monetize the social costs of transportation fail to capture the magnitude of the impacts in real terms, as they are represented here. A five-fold increase in death rates has real implications for societies and for individuals, and these impacts can be linked directly to VMT with reasonable reliability.

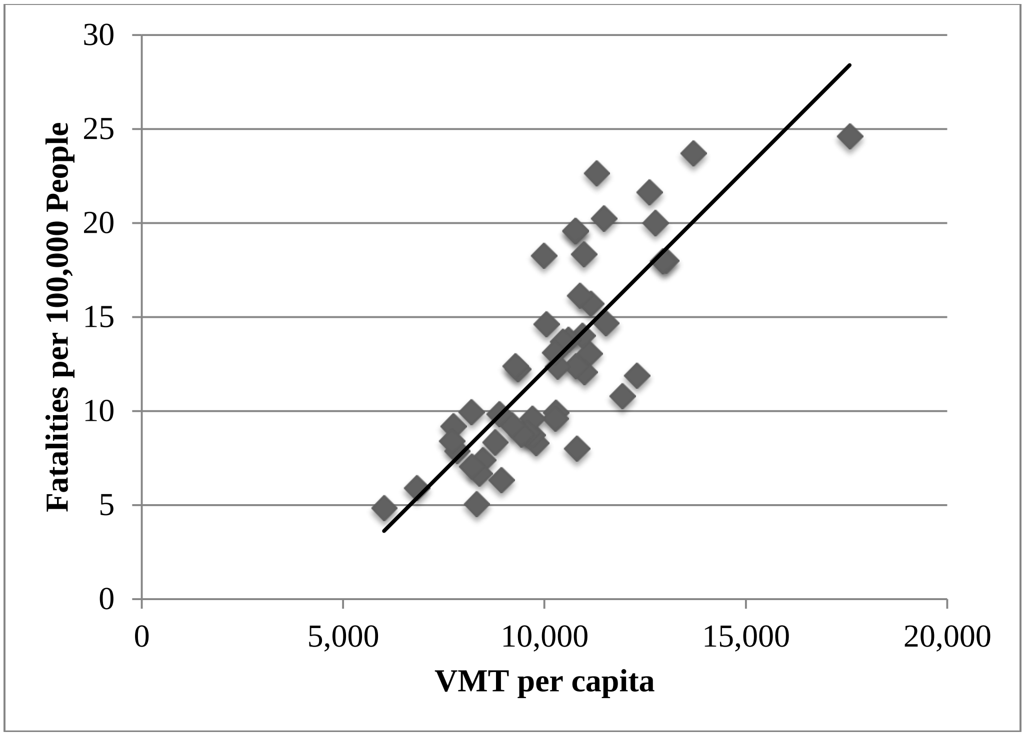

FIGURE 6: Relationship between VMT per capita and fatalities per 100,000 people, 2009

Environmental Costs

Given the growing concern about the impacts of CO_2 emissions and the acknowledgement that a considerable portion of these emissions is attributable to activities in the transportation sector, the authors of this study opted to utilize per capita CO_2 emissions as an indicator of environmental costs. Emissions of CO_2 from surface transportation were calculated according to the procedure outline by the International Panel on Climate Change (*110*).

As shown in Figure 7, the per capita emissions from motor gasoline and distillate fuels for each state are positively associated with VMT per capita ($R^2 = 0.53$). Highest per capita emissions are in Wyoming (13 Terragrams, Tg, of CO_2 equivalent per 1 million people) and lowest in Washington, D.C. (1.7 Tg of CO_2 eq.). In other words, an average person in Wyoming produces more than seven times the CO_2 than an average person in the District of Columbia, just by traveling. The differences in per capita CO_2 emissions are due in large part to the amount of vehicle travel occurring, where higher rates of travel as found in Wyoming, Mississippi, North Dakota and South Dakota generate four of the highest per capita emissions rates among the states. At the opposite end of the spectrum, of the ten states with the lowest VMT per capita, seven states also have the lowest CO_2 emissions (Washington, Massachusetts, Illinois, Rhode Island, Hawaii, New York and Washington, D.C.).

Given the magnitude of per capita emissions in many states, the measure of VMT per capita should be considered a valuable indicator of substantial environmental impacts from the transportation sector. There are some exceptions worth exploring, however. For example, the emissions rate in Arizona (10.8 Tg CO_2 eq.) is more than three times higher than the emissions rate in Arkansas (3.0 Tg CO_2 eq.) despite having a lower VMT rate.

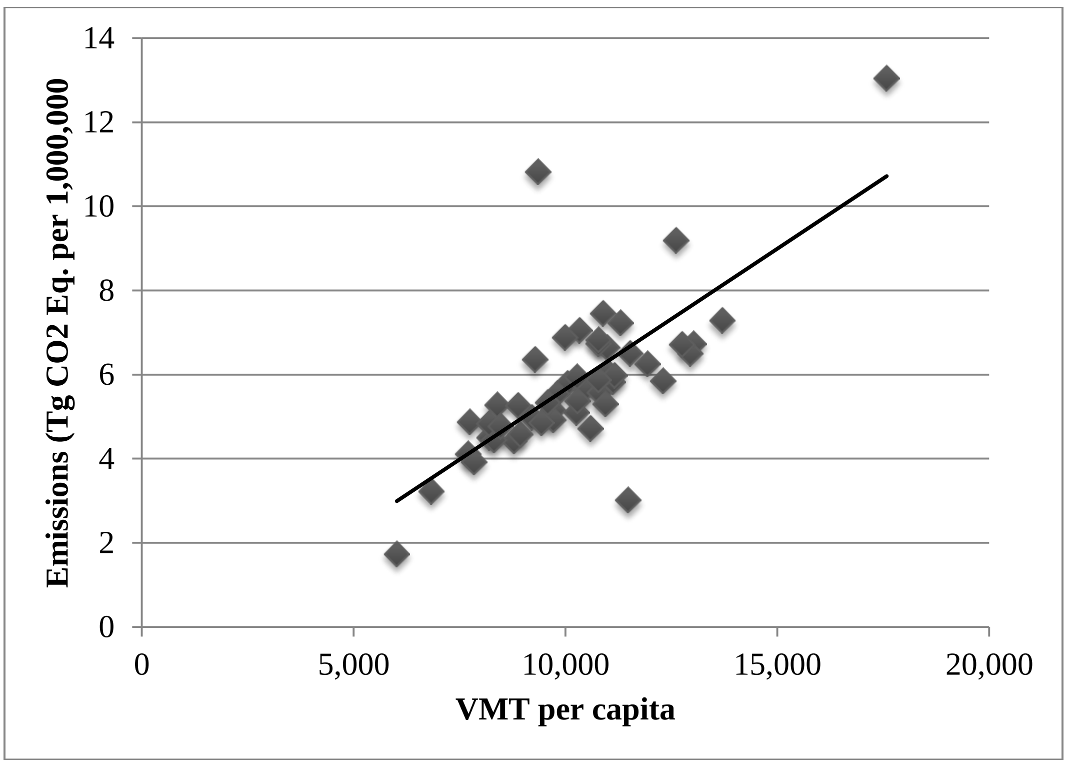

FIGURE 7: Relationship between VMT per capita and CO_2 emissions per capita, 2009

DISCUSSION AND CONCLUSIONS

The core questions proposed at the outset were: how do VMT and level of automobile-dependence interrelate, what are some of the costs associated with VMT, and how do they vary across states with different levels of VMT/automobility?

To address the first question, commuting data was used as an indicator of automobile dependence; where states with a higher percentage of workers commuting by private automobile are determined to be locations where commuters are more dependent on the automobile for accessing their work destinations. As might be expected, the states in which more residents commute using private automobiles are also the states with higher VMT per capita rates. In other words, if a lot of people are driving to get to work, they are accumulating miles in the process of those commutes so it is logical that more commuters driving will result in more miles driven. Workers that are reliant on the automobile are therefore responsible for higher rates of VMT. As such, VMT per capita is a reasonable indicator of the level of automobile-orientation of a state's transportation system.

With respect to costs associated with VMT, automobile transportation can mean considerable economic costs to both system-providers and system-users. VMT was found to be an indicator of these costs, with its strongest correlation at the household level where cost to households (as a percent of income) vary from 16% to 41%. In some instances, the cost burden appears to shift from government to household or vice-versa. Take for example, Arkansas, Tennessee and North Carolina which are among the states with the lowest government transportation spending per capita but who are all ranked in the top 10 in transportation costs for households. Connecticut, ranked 40th in VMT per capita, is one state where costs at both scales are on the low end: ranked 45th and 44th in transportation expenditures by governments and households, respectively. A resident of Wyoming or Montana is not quite as lucky as they bear a higher transportation cost burden through direct household costs and indirectly through tax-funded government expenditure. Wyoming governments spend the most per capita of any state on transportation while households have the second highest travel costs (as a percent of their income). Montana has the fourth highest government expenditure and its' households are fifth highest in share of income spent on transportation. For reference, Wyoming has the highest VMT per capita in the U.S. while Montana has the 12th highest rate.

While prior studies of the costs and benefits of transportation investments often monetize a variety of impacts, the above analysis considers only the direct monetary costs, which are substantial. The costs shown here are on the order of $46 of government spending per capita, 0.3% of GDP and 2% of household income for each additional 1,000 VMT per person.

In quantifying the social and environmental costs associated with automobile use for this study, the data was not monetized. This approach revealed that automobile use is associated with considerable social costs in terms of traffic fatalities and with environmental costs in terms of CO_2 emissions. The costs shown here are on the order of an increase of 2.2 fatalities per 100,000 people and 0.69 Tg CO_2 eq. per million people, for each additional 1,000 VMT per person accumulated.

At the state level, the costs associated with various levels of VMT vary but there are some notable trends. Of the top ten states in terms of VMT per capita, three states are also ranked in the top ten in at least four of the five cost categories analyzed in this paper while six states are ranked in the top ten in two or more of the cost categories. Indiana and Missouri are examples of how varied the states can perform as both are ranked in the top ten in VMT costs but are not top-ten ranked in any of the five costs analyzed in this paper. On the other end of the rankings, of the ten lowest VMT per capita states, four states are ranked among the lowest ten states for four of the five cost categories. For example, Rhode Island has the 46th rank VMT per capita rate (or 5th lowest) and is 50th in government spending on transportation, 46th in fuel spending, 43rd in fatalities and 47th in CO_2 emissions. An additional two states (Illinois and Washington) are in the lowest ten for VMT per capita and are also among the ten lowest states for three of the cost variables. Nevada is an anomaly: ranked 47th in VMT per capita but not benefitting notably from the low VMT as it does not make the lowest ten states for any of the costs discussed in this paper.

In attempting to account for the full costs of automobile-oriented systems to governments, to private users and to externally-affected parties, it becomes evident that there are considerable costs associated with car-centricity (*95-96,99*). This should be considered when weighing automobile investments against other transportation projects such as rail, even if the latter is often considered expensive and even unviable (Utsunomiya, 2011). Rather, as Levinson et al. (*111*) found, rail travel is only marginally more expensive than car travel and may be more beneficial once you factor in the environmental and societal benefits of providing rail as an alternative to being dependent on the automobile. All transport modes are subsidized to some level (*112*). It is easier to account for and calculate the subsidies to public transportation, however, than to add up the wide array and distribution of automobile subsidies to things like to road maintenance, law enforcement, emergency response budgets and provision public parking. Because of the complication of calculating the full subsidy to automobiles, let alone understanding the full subsidies, the numbers provided and then compared to transit subsidies are most likely severely underestimated.

It is evident from our results that the working assumption that car-based travel is cheaper and more efficient is not true. Consistent with McCann (*100*), geographic areas with fewer modal options end up costing more, not less, both to users and to the providers.

IMPLICATIONS FOR MANAGERIAL PRACTICE

The goal of this paper is to help inform the public debate regarding the role of automobile travel within the transportation system. One of the most visible government activities is the provision of transportation infrastructure and service. Governments have a responsibility to manage budgets in an appropriate and efficient manner. For decades, governments have been allured by the ease of a "mono-modal" transportation system that prioritized the automobile over other modes. It was easy to allow highway departments to assume the role of transportation departments and direct most, if not all, funding to highway construction and maintenance. It was thought to be cheaper and more efficient than trying to manage several different modes that could otherwise be competing for funding. The rise of fuel and material costs have not only slowed highway construction in recent years but also made maintaining existing roads and infrastructure a costly endeavor.

This paper questions the general assumption that it is cheaper to build a transportation system that prioritizes private automobile travel. The principal problem, as many critics have pointed out, is that many of the costs associated with freeway systems and automobile travel are externalized (*65,96,99,104*). Automobiles are not necessarily bad but rather are a very valuable part of any transportation system. The issue is, as Mumford (*33*) point out 50 years ago, that we need a transportation system which offers a variety of options to meet a diversity of human needs. By focusing only on the car, he predicted, we would cripple the car as a mode because it becomes responsible for bearing the burden of all modes.

If governments are to be responsible providers of public services, they should seek to build the most cost efficient transportation systems. Using state-level data, it was found that states that provide more transportation options (as evidenced in the rate of non-automobile commuting taking place) actually cost less per person than states which have chosen the car-centered approach. In addition, the states which have prioritized automobile travel over other modes are actually costing their households more money, to the tune of up to 41% of household income being spent on transportation. In other words, for every $10 earned, $4.10 is spent on transportation needs. As is evident, the impacts of automobile-oriented transportation systems are pronounced at the household level.

In terms of both economic and environmental responsibility, government leaders need to be aware of VMT rates as it pertains to CO_2 emission. Higher VMT per capita was found to be strongly related to increasing CO_2 emissions into the atmosphere that are experienced globally as a result. The environmental and societal consequences of increasing emissions and accelerated global warming are still yet to be fully understood yet Stern (*83*) found that damages from global warming could cost anywhere from 5% to 20% of the world's gross domestic product (GDP) to address and/or mitigate. Though the cost was estimated worldwide, the costs will no doubt be felt by states and localities alike.

Beyond fiscal responsibility, governments are responsible to protect the health, safety and general welfare of its citizenry. Based on the findings of this paper, prioritizing automobile travel at the expense of other modes can have dangerous consequences both for system users and externally. The number of deaths caused by motor vehicle accidents has been found to increase rapidly with increases in automobile travel. As a result, leaders should pursue policies that reduce VMT in order to reduce life lost in traffic accidents. Based on the state level data analyzed in this paper, cutting VMT by 50% could result in a 75% (possibly up to 80%) reduction of fatal car accidents. This means that for every 100 deaths, 75-80 people could still be alive if transportation systems were more diversified and less car-centric.

The goal of this paper was to inform the public debate in questioning some assumptions about the direct and indirect costs of automobile travel. Based on the findings of this paper, it costs more, not less, to focus a transportation system on automobiles alone as governments in states with high levels of automobile use also pay more to support their transportation systems. Oppositely, states with less automobile use benefit from economic, social and environmental savings at the household, government and societal levels as well as being better global stewards. These results show that diverse transportation systems actually cost less both to system providers and to system users. With system managers responsible for allocating resources in the most efficient and effective manner, these results show that it makes more fiscal sense to invest in a diversity of modes than to focus funding on one mode alone. An added benefit is more equitable access by lower income and non-driving populations to more affordable transportation systems. Policy-makers are therefore encouraged to revisit the ideas presented by Mumford (*33*) about the purpose of a transportation system:

> *"The purpose of transportation is to bring people and goods to places where they are needed, and to concentrate the greatest variety of goods and people within a limited area, in order to widen the possibility of choice without making it necessary to travel. A good transportation system minimizes unnecessary transportation…" (p.235-236).*

Much of the VMT growth in the United States is associated with the increase of "empty miles"—what Mumford may have termed "unnecessary transportation" that incurs economic, social and environmental costs. The analysis presented in this paper suggests that providing a diverse transportation system with modal options may be able to reduce automobile-related fatalities and carbon emissions associated with high VMT rates. The hope is that highlighting some of the costs (in economic, environmental and social terms) associated with high levels of VMT will help to inform the public debate about VMT-reduction policies and encourage a broader consideration of what costs need to be considered in the decision-making process that will encourage transportation sustainability.

REFERENCES

1. Debnath, A.K., M. Haque, H.C. Chin and B. Yuen. Sustainable urban transport: Smart technology initiatives in Singapore. In *Transportation Research Record (TRR): Journal of the Transportation Research Board (TRB), No. 2243*, TRB of the National Academies, Washington, D.C., 2011, pp.38-45.
2. Janic, M. Sustainable transport in the European Union: A review of the past research and future ideas. *Transport Reviews*, Vol.26, No.1, 2006, pp.81-104.
3. Prillwitz, J. and S. Barr. Moving towards sustainability? Mobility styles, attitudes and individual travel behaviour. *Journal of Transport Geography*, Vol.19, No.6, 2011, pp.1590-1600.
4. Meyer, M.D. Transport planning for urban areas: A retrospective look and future prospects. *Journal of Advanced Transportation*, Vol.34, No.1, 2000, pp.143-171.
5. Marshall, A. *How Cities Work: Suburbs, Sprawl, and the Roads Not Taken*. University of Texas Press, Austin, TX, 2000.
6. Wolman, H., G. Galster, R. Hanson, M. Ratcliffe, K. Furdell, and A. Sarzynski. The Fundamental Challenge in Measuring Sprawl: Which Land Should Be Considered? *The Professional Geographer*, Vol.57, No.1, 2005, pp. 84-105.
7. Squires, G.D. <u>Urban Sprawl: Causes, Consequences & Policy Responses</u>. The Urban Institute Press, Washington, D.C., 2002.
8. Badoe, D.A. and E.J. Miller. Transportation-land-use interaction: empirical findings in North America, and their implications for modeling. *Transportation Research Part D: Transport and Environment*, Vol.5, No.4, 2000, pp.235-263.
9. Bengston, D.N., J.O. Fletcher, and K.C. Nelson. Public policies for managing urban growth and protecting open space: policy instruments and lessons learned in the United State. *Landscape and Urban Planning*, Vol.69, No.2-3, 2004, pp.271-286.
10. Burchell, R., A. Downs, B. McCann, and S. Mukherji. *Sprawl Costs: Economic Impacts of Unchecked Development*. Island Press, Washington, D.C., 2005.
11. Carruthers, J.I. The impacts of state growth management programmes: A comparative analysis. *Urban Studies*, Vol.39, No.11, 2002, pp.1959-1982.
12. Frank, L.D., M.A. Andersen, and T.L. Schmidt. Obesity relationships with community design, physical activity, and time spent in cars. *American Journal of Preventative Medicine*, Vol.27, No.2, 2004, pp.87-96.
13. Stone Jr., B. Urban sprawl and air quality in large US cities. *Journal of Environmental Management*, Vol.86, No.4, 2008, pp.688-698.
14. Gonzalez, G.A. Urban Sprawl, Global Warming and the Limits of Ecological Modernisation. *Environmental Politics*. Vol.14, No.3, 2005, pp.344-362.
15. Haase, D., and H. Nuissi. Does urban sprawl drive changes in the water balance and policy? The case of Leipzig (Germany), 1870-2003. *Landscape and Urban Planning*, Vol. 80, Nos.1-2, 2007, pp.1-13.
16. Nelson, A.C. Economic critique of U.S. prime farmland preservation policies: Towards state policies that influence productive, consumptive, and speculative value components of the farmland market to prevent urban sprawl and foster agricultural production in the United States. *Journal of Rural Studies*, Vol.6, No.2, 1990, pp.119-142.

17. Gomez-Loscos, A., M.D. Gadea, and A. Montanes. Economic growth, inflation, and oil shocks: Are the 1970s coming back? *Applied Economics*, Vol.44, No.35, 2012, pp.4575-4589.
18. Guo, H., and K.L. Kliesen. Oil price volatility and U.S. macroeconomic activity. *Federal Reserve Bank of St. Louis Review*, Vol. 87, No.6, 2005, pp.669-683.
19. Klare, M.T. *Blood and Oil: The Dangers and Consequences of America's Growing Dependency on Imported Petroleum*. Owl Books, Henry Holt and Company, LLC., New York, NY, 2005.
20. Rafig, S., R. Salim, and H. Bloch. Impact of crude oil price volatility on economic activities: An empirical investigation in the Thai economy. *Resources Policy*, Vol. 34, No.3, 2009, pp.121-132.
21. Parry, I.W.H., M. Walls, and W. Harrington. Automobile Externalities and Policies. *Journal of Economic Literature*, Vol.45, No.2, 2007, pp.373-399.
22. Shirley, C., and C. Winston. Firm inventory behavior and the returns from highway infrastructure investments. *Journal of Urban Economics*, Vol. 55, No.2, 2004, pp.398-415.
23. Anderson, D.M., and D.I. Rees. *Discussion Paper No. 6112: Medical Marijuana Laws, Traffic Fatalities, and Alcohol Consumption*. IZA, 2011. http://ftp.iza.org/dp6112.pdf Accessed October 21, 2012.
24. Centers for Disease Control and Prevention. *Web-based Injury Statistics Query and Reporting System*. 2010. http://www.cdc.gov/injury/wisqars. Accessed October 21, 2012.
25. Colvile, R.N., S. Kaur, R. Britter, A. Robins, M.C. Bell, D. Shallcross, and S.E. Belcher. Sustainable development of urban transport systems and human exposure to air pollution. *Science of the Total Environment*, Vols. 334-335, 2004, pp.481-487.
26. Pardo, C.F. *Shanghai Manual: A Guide for Sustainable Urban Development in the 21st Century, Chapter 4*. United Nations, 2011. http://www.un.org/esa/dsd/susdevtopics/sdt_pdfs/shanghaimanual/Chapter%204%20-%20Sustainable%20urban%20transport.pdf. Accessed October 21, 2012.
27. Rodrigue, J-P, C. Comtois, and B. Slack. *The Geography of Transport Systems, Second Edition*. Routledge, New York, NY, 2009.
28. Cortright, J. *Measuring Urban Transportation Performance: A Critique of Mobility Measures and a Synthesis*. CEOs for Cities, 2010. http://www.ceosforcities.org/research/driven-apart. Retrieved May 25, 2012.
29. Noland, R.B., and L.L. Lem. A review of the evidence for induced travel and changes in transportation and environmental policy in the US and the UK. *Transportation Research Part D: Transport and Environment*, Vol.7, No.1, 2002, pp1-26.
30. Kooshian, C., and S. Winkelman. *Growing Wealthier: Smart Growth, Climate Change, and Prosperity*. Center for Clean Air Policy, 2011. http://www.growingwealthier.info/index.aspx. Accessed October 26, 2011.
31. U.S. DOT, Federal Highway Administration (FHWA). *Highway Statistics 2009, Table VM-202: Annual Vehicle-Miles of Travel, 1980-2009*. 2012. http://www.fhwa.dot.gov/policyinformation/statistics/2009/vm202.cfm. Accessed May 31, 2012.
32. Jacobs, J. *The Death and Life of Great American Cities*. Random House, New York, NY, 1961.
33. Mumford, L. *The Highway and the City*. Harcourt, Brace & World , New York, NY, 1963.
34. Calthorpe, P. *The Next American Metropolis: Ecology, Community and the American Dream*. Princeton Architectural Press, New York, NY, 1993.
35. Congress for the New Urbanism. *Charter of the New Urbanism*. 2001. http://www.cnu.org/charter. Accessed October 20, 2012.
36. Carruthers, J.I. The impacts of state growth management programmes: A comparative analysis. *Urban Studies*, Vol.39, No.11, 2002, pp.1959-1982.
37. U.S. EPA. *Smart Growth Illustrated*. 2012. http://www.epa.gov/dced/case.htm. Accessed October 20, 2012.
38. Talen, E. *New urbanism and American planning: the conflict of cultures*. Routledge, New York, NY, 2005.

39. U.S. EPA. *HUD-DOT-EPA Partnership for Sustainable Communities*. 2012. http://www.epa.gov/dced/partnership/. Accessed August 26, 2012.
40. Blanco, H. *Measuring Urban Sustainability*. American Planning Association, 2012. http://www.planning.org/education/webinars/2012/pdf/evidenceoutline.pdf. Accessed October 20, 2012.
41. Dixon, J.A., and L.A. Fallon. The concept of sustainability: Origins, extensions, and usefulness for policy. *Society & Natural Resources: An International Journal*, Vol.2, No.1, 1989, pp.73-84.
42. Drexhage, J., and D. Murphy, D. *Sustainable Development: From Brundtland to Rio 2012*. International Institute for Sustainable Development , New York, NY, 2010.
43. Stirling, A. The appraisal of sustainability: Some problems and possible responses. *Local Environment: The International Journal of Justice and Sustainability*, Vol.4, No.2, 1999, pp.111-135.
44. Centre for Sustainable Transportation (CST). *Defining Sustainable Transportation: Prepared for Transport Canada*. 2005. http://cst.uwinnipeg.ca/documents/Defining_Sustainable_2005.pdf. Accessed October 21, 2012.
45. Ewing, R. Measuring Transportation Performance. *Transportation Quarterly*, Vol.49, No.1, 1995, pp.91-104.
46. Litman, T. Letter to Editor (Response to Alan Pisarski's article "The Nexus of Energy, Environment and the Economy: A Win, Win, Win Opportunity"). *ITE Journal*, May 2009, pp.12-13. http://www.vtpi.org/ITE_letter_may2009.pdf 2009. Accessed November 2, 2011.
47. Mihyeon, J.C., and A. Amekudzi, A. Addressing Sustainability in Transportation Systems: Definitions, Indicators, and Metrics. *Journal of Infrastructure Systems*, Vol.11 (Special Issue: Sustainability of Transportation and Other Infrastructure Systems), 2005, pp.31-50.
48. Zheng, J., C. Atkinson-Palombo, C. McCahill, R. O'Hara, and N.W. Garrick. Quantifying the Economic Domain of Transportation Sustainability. *TRR: Journal of the TRB*, Vol. 2242, 2011, pp.19-28.
49. Moore, A.T., S.R. Staley, and R.W. Poole. The role of VMT reduction in meeting climate change policy goals. *Transportation Research Part A: Policy & Practice,* Vol.44, No.8, 2010, pp.565-574.
50. U.S. DOT, FHWA, Office of Highway Policy Information. *Table HM-20: Public Road Length - 2010*. 2011. http://www.fhwa.dot.gov/policyinformation/statistics/2010/hm20.cfm. Accessed May 9, 2012.
51. U.S. Department of Energy (DOE). *Fact #617: Changes in Vehicles per Capita around the World*. 2010. http://www1.eere.energy.gov/vehiclesandfuels/facts/2010_fotw617.html. Accessed October 20, 2012.
52. U.S. DOE. *Transportation Energy Data Book, Edition 31: Table 8.1 Population and Vehicle Profile, 1950-2010*. 2012. http://cta.ornl.gov/data/chapter8.shtml. Accessed October 20, 2012.
53. Millard-Ball, A., and L. Schipper. Are We Reaching Peak Travel? Trends in Passenger Transport in Eight Industrialized Countries. *Transport Reviews: A Transnational Transdisciplinary Journal*, Vol.31, No.3, 2011, pp.357-378.
54. Currie, G., and J. Phung. Understanding links between transit ridership and gasoline prices: Evidence from the United States and Australia. TRR: Journal of the TRB, Vol. 2063, 2008, pp.133-142.
55. Metz., D. Demographic determinants of daily travel demand. *Transport Policy,* Vol.21, 2012, pp.20-25.
56. Brown, L. *U.S. Car Fleet Shrank by Four Million in 2009*. Earth Policy Institute, 2010. http://www.earth-policy.org/index.php?/plan_b_updates/2010/update87. Accessed November 5, 2011.
57. Burden, D. and T. Litman. America Needs Complete Streets. *Institute of Transportation Engineers ITE Journal*, Vol.81, No.4, 2011, pp.36-43.

58. Storper, M., and M. Manville. Behaviour, preferences and cities: Urban theory and urban resurgence. *Urban Studies*, Vol. 43, No.8, 2006, pp.1247-1274.
59. Kane, L., and R. Del Mistro. Changes in transport planning policy: Changes in transport planning methodology? *Transportation*, Vol.30, No.2, 2003, pp.113-131.
60. Owens, S. From “predict and provide” to “predict and prevent”?: pricing and planning in transport policy. *Transport Policy*, Vol. 2, No.1, 1995, pp.43-49.
61. Schrank, D., T. Lomax, and W. Eisele. *Texas Transportation Institute’s 2011 Urban Mobility Report: Powered by INRIX Traffic Data*. Texas Transportation Institute at the Texas A&M University System, 2011. http://mobility.tamu.edu/ums/report/. Accessed May 15, 2012.
62. Dajani, J.S., and G. Gilbert, G. Measuring the performance of transit systems. *Transportation Planning and Technology*, Vol.4, No.2, 1978, pp.97-103.
63. U.S. DOT. *Transportation’s Role in Reducing U.S. Greenhouse Gas Emissions Volume 1: Synthesis Report*. 2010. http://ntl.bts.gov/lib/32000/32700/32779/DOT_Climate_Change_Report_-_April_2010_-_Volume_1_and_2.pdf. Accessed December 5, 2011.
64. Cowling, E.B., D.S. Shriner, J.E. Barnard, A.A Lucier, A.H. Johnson, and A.R. Kiester. *Airborne Chemicals and Forest Health in the United States. Proceedings of World Congress, International Union of Forestry Research Organizations, Report B*, 1990, pp.25-36.
65. Murphy, J.J., M.A. Delucchi, D.R. McCubbin, and H.J. Kim. The Cost of Crop Damage Caused by Ozone Pollution from Motor Vehicles. *Journal of Environmental Management*, Vol. 55, No. 4, 1999, pp.273-289.
66. Dockery, D.W., A. Pope, X. Xu, J.D. Spengler, J.H. Ware, M.E. Fay, B.G Ferris, and F.E. Speizer. An Association between Air Pollution and Mortality in Six U.S. Cities. *New England Journal of Medicine*, Vol. 329, No.24, 1993, pp.1754-1808.
67. Pope, C.A., M.J. Thun, M.M. Namboodiri, D.W. Dockery, J.S. Evans, F.E. Speizer, and C.H Heath. Particulate Air Pollution as a Predictor of Mortality in a Prospective Study of U.S. Adults. *American Journal of Respiratory and Critical Care Medicine*, Vol. 151, No.3, 1995, pp.669-674.
68. U.S. EPA. *EPA’s Fuel Economy and Emissions Programs*. 2004. http://www.epa.gov/fueleconomy/420f04053.htm. Accessed May 17, 2012.
69. U.S. EPA. *Emission Standards Reference Guide*. 2009. http://www.epa.gov/otaq/standards/index.htm. Accessed May 17, 2012
70. U.S. EPA. *Inventory of U.S. Greenhouse Gas Emissions & Sinks: 1990-2009, Executive Summary*. 2011. http://epa.gov/climatechange/emissions/downloads11/US-GHG-Inventory-2011-Executive-Summary.pdf. Accessed December 20, 2011.
71. U.S. Energy Information Administration. Emissions of Greenhouse Gases Report. 2009. http://www.eia.gov/oiaf/1605/archive/gg09rpt/index.html. Accessed May 23, 2012.
72. Mui, S., J. Alson, B. Ellies, and D. Ganss. *A Wedge Analysis of the U.S. Transportation Sector*. Environmental Protection Agency, 2007. <http://www.epa.gov/oms/climate/420r07007.pdf>. Accessed May 23, 2012.
73. Burbank, C.J., and P. Brinckerhoff. *Strategies for Reducing the Impacts of Surface Transportation on Global Climate Change: A Synthesis of Policy Research and State and Local Mitigation Strategies. National Highway Cooperative Research Program Project, 20-24(59)*. American Association of State Highway and Transportation Officials (AASHTO), 2009 : http://climatechange.transportation.org/pdf/nchrp_2024_59_final_report_031309.pdf. Accessed March 5, 2012.
74. Cervero, R., and J. Murakami. Effects of built environments on vehicle miles traveled: evidence from 370 US urbanized areas. *Environment and Planning A*, Vol. 42, No. 2, 2010, pp.400-418.
75. Andrews, C.J. Greenhouse gas emissions along the rural-urban gradient. *Journal of Environmental Planning and Management*, Vol. 51, No.6, 2008, pp.847-870.

76. U.S. EPA. *Partnership for Sustainable Communities: A Year of Progress for American Communities*. 2010. http://www.epa.gov/dced/pdf/partnership_year1.pdf. Accessed May 23, 2012.
77. Ewing, R., K. Bartholomew, S. Winkelman, J. Walters, and D. Chen. *Growing Cooler: The Evidence on Urban Development and Climate Change.* Urban Land Institute, Chicago, IL, 2008.
78. Malaczynski, J.D. Reducing Greenhouse Gas Emissions from Vehicle Miles Traveled: Integrating the California Environmental Quality Act with the California Global Warming Solutions Act. *Ecology Law Quarterly* Vol.36, No.1, 2009, pp.71-135.
79. Nagurney, A., Q. Qiang, and L.S. Nagurney. Environmental Impact Assessment of Transportation Networks with Degradable Links in an Era of Climate Change. *International Journal of Sustainable Transportation*, Vol.4, No.3, 2010, pp.154-171.
80. Pisarski, A. *ULI Moving Cooler Report: Greenhouse Gases, Exaggerations and Misdirections*. New Geography, 2009. http://www.newgeography.com/content/00932-uli-moving-cooler-report-greenhouse-gases-exaggerations-and-misdirections. Accessed November 2, 2011.
81. Cambridge Systematics, Inc. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions*. Urban Land Institute, Washington, D.C., 2009.
82. McKinsey & Company. *Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost? U.S. Greenhouse Gas Abatement Mapping Initiative Executive Report*. 2007. http://www.mckinsey.com/Client_Service/Sustainability/Latest_thinking/Reducing_US_greenhouse_gas_emissions. Accessed May 16, 2012.
83. Stern, N. *Stern Review: The Economics of Climate Change*. Cambridge University Press, Cambridge, UK, 2006.
84. Transportation Research Board. *Special Report 290: Potential Impacts of Climate Change on U.S. Transportation.* 2008. http://onlinepubs.trb.org/onlinepubs/sr/sr290.pdf. Accessed August 26, 2012.
85. Koetse, M.J., and P. Rietveld, P. The impact of climate change and weather on transport: An overview of empirical findings. *Transportation Research Part D: Transport & Environment*, Vol.14, No.3, 2009, pp.205-221.
86. Deakin, E. *Sustainable Development and Sustainable Transportation: Strategies for Economic Prosperity, Environmental Quality, and Equity*. 2001. http://escholarship.org/uc/item/0m1047xc. Accessed November 16, 2011.
87. Transportation Research Board. *Special Report 251: Toward a Sustainable Future: Addressing the Long-Term Effects of Motor Vehicle Transportation on Climate and Ecology*. 1997. http://onlinepubs.trb.org/onlinepubs/sr/sr251.pdf. Accessed May 19, 2012.
88. Jacobs, E., and S. Shipp. How family spending has changed in the US. *Monthly Labor Review*, Vol.113, No.3, 1990, pp.20-27.
89. Polzin, S.E. *The Case for Moderate Growth in Vehicle Miles of Travel: A Critical Juncture in U.S. Travel Behavior Trends*. Prepared for U.S. Department of Transportation, 2006. http://www.cutr.usf.edu/pdf/The%20Case%20for%20 Moderate%20Growth%20in%20VMT-%202006%20Final.pdf. Accessed May 18, 2012.
90. Pisarski, A. *Travel Behavior Issues in the 90s*. Federal Highway Administration, Washington, D.C., 1992.
91. Banister, D. Influence of habit formation on modal choice – heuristic model. *Transportation* Vol.7, No.1, 1978, pp.5-18.
92. Banister, D. *Car Availability and Usage: A Modal Split Model Based on these concepts, Geographical Pape No. 58*. University of Reading, Department of Geography, Reading, UK, 1977.
93. Bowman, M., 2011. *Analysis of Vehicle Miles Traveled (VMT), GDP, and Gas Prices. 3G Mobility, LLC, 2011*. http://www.scribd.com/doc/51841381/Vehicle-Miles-Traveled-VMT-Gas-Prices-and-GDP-Analysis-March-2011. Accessed November 5, 2011.

94. Delucchi, M.A. *Personal Nonmonetary Costs of Motor-Vehicle Use: Report #4 in the series: The Annualized Social Cost of Motor-Vehicle Use in the United States, Based on 1990-1991 Data*. Institute of Transportation Studies, University of California, Davis,1996.
95. Beshers, E. *External costs of automobile travel and appropriate policy responses*. Highway Users Federation, Washington, D.C., 1994.
96. Delucchi, M.A. *The annualized social cost of motor-vehicle use in the U.S., 1990-1991: Summary of theory, data, methods and results*. USDOT, 1998. http://www.fhwa.dot.gov/scalds/delucchi.pdf. Accessed June 27, 2012.
97. Litman, T. *Evaluating criticism of transportation costing.* Victoria Transport Policy Institute, 1999. http://www.vtpi.org/critics.pdf. Accessed June 27, 2012.
98. Litman, T. *The costs of automobile dependency and the benefits of balanced transportation.* Victoria Transport Policy Institute, 2002: <http://www.vtpi.org/autodep.pdf>. Accessed June 27, 2012.
99. Delucchi, M.A., and J.J. Murphy. *Motor-Vehicle Infrastructure and Services Provided by the Public Sector: Report #7 in the series: The Annualized Social Cost of Motor-Vehicle Use in the United States, based on 1990-1991 data*. Institute of Transportation Studies, University of California, Davis, 2005.
100. McCann, B. *Driven to Spend: The Impact of Sprawl on Household Transportation Expenses*. Surface Transportation Policy Partnership, 2000. http://www.transact.org/report.asp?id=36. Accessed December 5, 2011.
101. Bishai, D., A. Quresh, P. James, and A. Ghaffar. National road casualties and economic development. *Health Economics* Vol.15, No.1, 2006, pp.65-81.
102. Traynor, T.L. The Relationship between Regional Economic Conditions and the Severity of Traffic Crashes. *Traffic Injury Prevention* Vol.10, No.4, 2009, pp.368-374.
103. Marshall, W.E., and N.W. Garrick. *Street Network Types and Road Safety: A Study of 24 California Cities.* Sacramento Area Council of Governments, 2009. http://www.sacog.org/complete-streets/toolkit/files/docs/Garrick%20&%20Marshall_Street%20Network%20Types%20and%20Road%20Safety.pdf. Retrieved November 23, 2011.
104. Edlin, A.S., and P. Karaca-Mandic. The accident externality from driving. *Journal of Political Economy*, Vol.114, No.5, 2006, pp.931-955.
105. Nelson, A.C., and T. Moore. Assessing urban growth management: The case of Portland, Oregon, the USA's largest urban growth boundary. *Land-use Policy*, Vol.10, No.4, 1993, pp.293-302.
106. Holmes, J., and J. van Hemert. *The Rocky Mountain Land-use Institute Sustainable Community Development Code Research Monologue Series on Urban Form and Transportation: Transit Oriented Development*. University of Denver, 2008. http://www.law.du.edu/images/uploads/rmlui/rmlui-sustainable-transitOrientedDevelopment.pdf. Accessed October 21, 2012.
107. Salkin, P., and A. Lavine, A. Land-use Law and Active Living: Opportunities for States to Assume a Leadership Role in Promoting and Incentivizing Local Options. *Rutgers Journal of Law and Urban Policy*, Vol.5, No.2, 2008, pp.317-360.
108. Litman, T. *Well Measured: Developing Indicators for Sustainable and Livable Transport Planning*. Victoria Transport Policy Institute, 2012. http://www.vtpi.org/wellmeas.pdf. Accessed October 30, 2012.
109. U.S. Department of Commerce, U.S. Census Bureau. *Table 14, State Population – Rank, Percent Change, and Population Density: 1980 to 2010*. 2010. http://www.census.gov/compendia/statab/2012/tables/12s0014.pdf. Accessed January 28, 2013.

110. Intergovernmental Panel on Climate Change (IPCC). *IPCC Guidelines for National Greenhouse Gas Inventories*. Prepared by the National Greenhouse Gas Inventories Programme, Japan, 2006. http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html. Accessed May 2, 2012.
111. Levinson, D., J.M. Mathieu, D. Gillen, and A. Kanafani. The full cost of high-speed rail: An engineering approach. *Annals of Regional Science*, Vol.31, No.2, 1997, pp.189-215.
112. American Public Transportation Association. *An Inventory of the Criticisms of High-Speed Rail with Suggested Responses and Counterpoints*. American Public Transportation Association, 2012. <http://www.apta.com/resources/reportsandpublications/Documents/HSR-Defense.pdf>. Accessed September 3, 2012.

CHAPTER 2: PEAK CAR TRAVEL AND THE DECOUPLING OF VEHICLE TRAVEL FROM THE ECONOMY: A SYNTHESIS OF THE LITERATURE

Published Work:
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ABSTRACT

Decades of growth in overall and per capita automobile use lead many to believe that driving rate increases would occur indefinitely. In the mid-2000's, driving levels in the United States and other developed countries peaked and then began to decline. Referred to as "peak travel," this international phenomenon is occurring in places with very different urban layouts, densities and demographics, suggesting this is a fundamental shift in travel behavior. Simultaneously, after 70 years of concurrent growth, the complex relationship between the economy (as measured by Gross Domestic Product or GDP) and personal vehicle travel appears to be changing; suggesting a weakening connection between the two. This paper reviews the literature regarding the current understanding and potential causes of these revolutionary trend reversals. While causes such as saturation of demand, aging, decline of young drivers, preference shifts and time budget constraints all contribute to reduced automobile travel at one time or another, or in one place or another, none of them can explain why peak car travel is occurring on multiple scales in a diversity of places. We conclude that, though the existing literature explains the recent trend reversal in specific cities or partially explains the global phenomenon, the fundamental reasons for peak car travel are still not understood. We challenge fellow researchers to explain these phenomena to more accurately and efficiently plan transportation infrastructure in the future.

INTRODUCTION

Automobile travel has dominated the way people choose residences, commute and live out their lives in the United States (U.S), creating an automobile-oriented society that demands maintained, free-flowing roadways. Once policy-makers chose to rely solely on this travel mode, they became responsible for relieving congestion. Through the cycle of induced travel (*1-2*), each highway improvement generated new demand and resulted in additional congestion (*3*). This predict-and-provide approach utilized observed driving rates (Vehicle Miles Traveled, VMT, in the U.S. and Vehicle Kilometers Traveled, VKT, in other countries) as its mobility measure with increased driving levels assumed to represent mobility success. Despite predictions that vehicle ownership saturation would serve to stabilize driving rates in the early 1990's (*4*), driving levels continued to grow until 2004, when per capita driving rates reached a plateau and then began to decline (See Figure 1; *9-10*). This new trend, labeled "peak travel" (*11*) or "peak car" (*12-13*) and referred to as "peak car travel" in this article, is so different from prior decades of vehicle travel growth, it is considered a new era of travel (*14*). It is unclear if peak car travel is permanent or temporary, leaving some to suggest that economic improvements could foster a return to increased driving levels (*15-17*). For example, 2013 traffic volume trends have shown driving levels are increasing when compared to the prior two years; however they are still well below the 2004 peak (*18*).

Initially, the economic recession of 2008 and record-high fuel prices were identified as reasons for reduced driving (*12*). Further investigation found that peak car travel began prior to these economic factors (*11,15,19*). A second divergence from past trends, what some are calling a "decoupling," is the apparent weakening of an assumed connection between personal vehicle travel and economic growth (as measured by Gross Domestic Product, GDP) (*19-20*). For decades in the U.S., VMT and GDP grew in a highly-correlated manner that suggested intricate connectivity (*21*). In the mid-1990's, GDP began growing faster than VMT, suggesting a weakening in driving's contribution to economic growth and calling the nature of the relationship into question (*20, 22*). As the U.S. economy recovers and driving rates stagnate or decline, the continued assumption of connectivity between driving and the economy may no longer be justified.

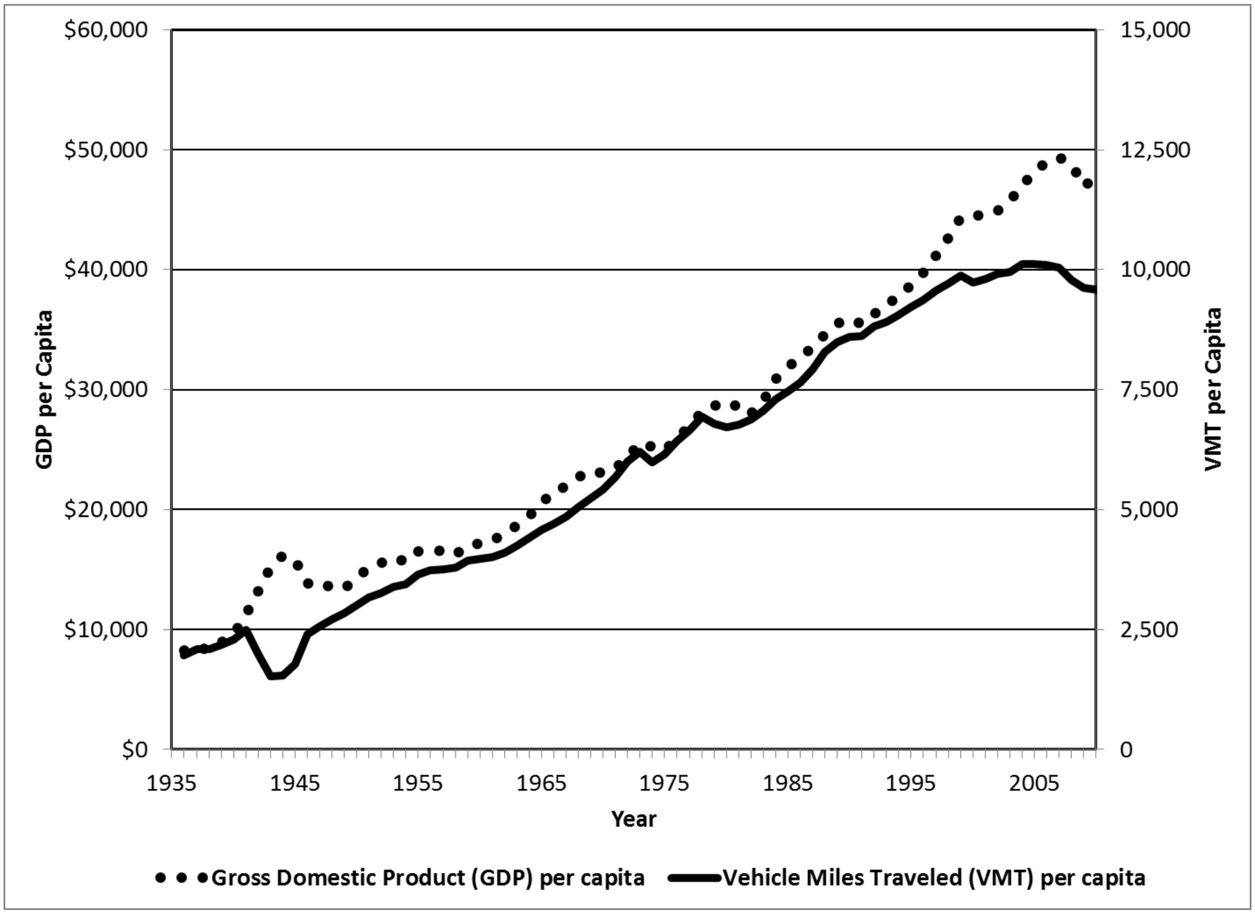

FIGURE 1: VMT per capita and GDP per capita in the U.S., 1936-2011 (*5-8*).

The reasons for peak car travel are undetermined despite occurring internationally (*23-24*). To lay out the context of this phenomenon, we discuss the use of observed driving levels in transportation planning then the potential relationship between driving and the economy, considering their similar historic growth and recent trend reversals. We then summarize the factors that impact vehicle travel rates before reviewing the literature on what may have caused the peak car travel phenomenon.

SIGNIFICANCE OF PERSONAL VEHICLE TRAVEL

The amount of driving per person, as measured by VMT per capita in the U.S. or VKT per capita elsewhere, is a widely used indicator of driving behavior and system performance because it is easy to measure, readily available and easily-transferrable across geographies (*20, 24*). There are limitations, however, since these data neither provide indications of available capacities, congestion, or vehicle fuel efficiencies, nor do they account for non-automobile travel (*9, 20*). Despite many limitations, vehicle travel per capita data have been used as critical transportation planning and funding metrics. For decades, transportation planners made assumptions about future travel behavior and associated congestion levels by using observed vehicle travel per capita increases to expand highway systems, ultimately inducing new driving and congestion rather than reducing it (*2-3, 9, 17*). The Urban Mobility Report, created annually by the Texas Transportation Institute, is a widely-referenced document that analyzes congestion levels in the largest U.S. cities. The 2012 Report (*17*) incorporates pre-Recession driving patterns and ignores peak car travel in calculating projected congestion levels. As a result, they determine that congestion costs will increase by $88 billion from 2011 to 2020 and recommend highway improvements to reduce anticipated congestion.

Personal driving data are also intricately connected to transportation finance where budgeting and fuel tax revenues often rely on predicted growth in driving rates (*9*). In the U.S., federal, state and county governments often use observed VMT totals to determine funding allocations to transportation agencies within their jurisdictions (*9, 25-26*) such that higher-VMT regions receive larger revenue allocations (*25*). Despite increased VMT from 1980 to 2000, fuel efficiency improvements actually resulted in a reduction in gas tax revenues and created billions of dollars in revenue shortfalls (*9*).

The U.S. Energy Information Administration's (EIA) Annual Energy Outlook utilizes VMT data to calculate and project the transportation sector's energy use. The 2013 EIA report (*27*) still does not acknowledge the peak car travel phenomenon and assumes continued growth in driving. The EIA estimates that driving will grow 1.2% annually from 2010 through 2040; equating to a 40.1% increase in overall VMT from 2.65 trillion to 3.72 trillion by 2040. Transportation planning and budgeting are typically based on EIA projections, so continued growth predictions while driving actually stagnates or decreases will result in unnecessary system expansions and create larger funding shortfalls over time. If vehicle travel continues to decline, its usefulness as an indicator in modeling and funding mechanisms will decline as well (*9*). The current reversal in the trajectory of driving may indicate a need to shift away from automobile travel-based, predict-and-provide approaches and towards innovative and more dynamic approaches to measuring, modeling and planning for travel behavior (*14, 16*); requiring entirely different funding and allocation programs in order to reflect changing demands (*14, 16*).

RELATIONSHIP BETWEEN VEHICLE TRAVEL AND THE ECONOMY

Historic Trends

Since U.S. VMT data were first available in 1936, VMT and GDP have been so closely correlated that they have been referred to as moving in "lockstep" with one another (See Figure 1; *16, 20-21, 28-29*). Regarding causality, existing research has competing conclusions: vehicle travel drives GDP (*29*), GDP facilitates increases in driving (*28, 30*), and the relationship varies based on time, space and population size (*28*). Strong bi-directional causality existed from 1949 to 1981 due to interstate construction (*28*) but after 1982 the relationship became highly variable, particularly because long-term economic development impacts city growth, size and layout, all of which have various impacts on travel behavior (*19, 28*). Additional complexities arise from the mutual causation of income, vehicle ownership and gas prices (*31*) that all interact with vehicle travel in different manners. For example, in OECD (Organization for Economic Cooperation and Development) countries, income levels and vehicle ownership rates were found to positively impact driving rates and gasoline consumption long-term while gas prices were found to have an inverse effect (*31*).

Traffic congestion, defined as traveling half the free-flow speed due to high traffic volumes (*32)*, is considered to be connected to economic vitality as well since employment increases and congestion increases co-occur (*17, 33-34*). San Francisco's simultaneous boom-and-bust of wealth and traffic during the dot.com era is identified as an example of the congestion-economy connection (*33*). A USDOT report (*35*) on congestion trends in urban areas links traffic to economic standing, stating that as the economy improves we will need improved strategies to handle the resulting increased congestion. Despite the complex connection between driving and wealth, some people have interpreted the relationship as evidence that reducing vehicle travel would automatically reduce GDP, and have used this argument to oppose any climate change policies that incorporate vehicle travel reductions (*29, 36*).

Recent Trend Reversals

In the U.S., overall national VMT (*9*) and VMT per capita (*9, 12, 16, 37-38*) plateaued in 2004 and began to decline in 2007 – the first decline since 1980. Prior to peak car travel, historic vehicle travel growth showed regional variations with higher growth in the south and west (*9*). Driving reductions were first evident in Vermont and Indiana in 2006, and became a nationwide phenomenon by 2008 when 48 states posted reduced per capita driving rates (*9*). Though now nationwide, there are large variations as many rural states post 12,000-18,000 VMT per capita, while some urbanized northeastern states have less than 7,000 VMT per capita (*39*). It is still unclear if this is a permanent phenomenon or temporary hiatus. It is notable however, that peak car travel is not limited to the U.S. but is being observed in other developed cities (*9, 12, 23*) and countries (*11, 22, 24*). Australia, Britain, France and Germany are exhibiting peak car travel indicators in some manner (*15, 40-43*). Australia's peak coincided with the U.S. peak in 2004 (*42*) while France's began in the late 1990's (*15*).

Schipper (*24*) found that growth in per capita driving has stopped in most countries but has occurred "most dramatically in the U.S., when compared with GDP/capita" (p.369). As the economy recovers without simultaneous vehicle travel growth, any assumed connection between the two variables appears to be weakening (*11, 16, 22, 41, 44*). In the U.S., driving per person dropped 6% from 2005 to 2010 even though GDP grew 8% during the same period (*44*). This "decoupling" may have begun as early as 1982 when previously-observed bidirectional causation between the two variables ceased to exist (*28*) or possibly during the mid-1990's when GDP and personal income began to grow faster than vehicle travel growth, suggesting a declining contribution of driving to economic activity (*20, 22*) and that the requirement for increased vehicle travel to grow the economy may no longer exist (*21, 41, 44*).

FACTORS IMPACTING TRAVEL BEHAVIOR

To understand why peak car travel is occurring, it is essential to understand what has been generating vehicle travel growth in prior decades. Modal choice and travel behavior are impacted by a complex set of factors that fall into two general categories: 1) built environment (*30, 45*-*51*); and 2) socioeconomic (*47*, *49*).

Built Environment Factors

Existing research suggests that combinations of land use attributes – rather than any one attribute in isolation – affect travel behavior. Initially these were referred to as the "3 D's" – density (of population and/or employment), diversity (of land uses), and design (*45*). The nomenclature has since been extended to the "6 D's" to also include destination accessibility (*46*); distance to transit (*47*); and demand management practices (*48*). For decades, the majority of development in the U.S. was low-density, residential suburbs connected by large arterial roads not easily serviced by transit or proximate to other uses. Applying the 6 D's, this development pattern reduced overall accessibility and required automobile trips to meet daily needs, increasing overall driving rates. Many land use policies are using the 6 D's classification to increase accessibility and reduce the need to drive (*51*). With respect to density, increasing residential densities by 10% was found to cause only marginal decreases in driving (less than 1%; *52*-*53*), but a doubling of residential densities could reduce driving up to 12% and, when combined with increased employment densities and transit opportunities, could facilitate a 25% reduction (*50*). Some have determined that any direct connection between residential densities and vehicle travel is inconclusive (*54*-*55*) but there is evidence that vehicle ownership levels may be a mediating variable such that higher densities reduce vehicle ownership which, in turn, reduces automobile travel (*52*-*54*).

Neighborhood location and layout was found to impact travel behavior such that U.S. residents in traditional and new urbanist-style neighborhoods drive anywhere from 5 VMT *per household* (*56*) to 5 VMT *per adult* in each household (*57*) less than their counterparts living in automobile-oriented sprawling neighborhoods, with the potential savings of up to 14.7 miles per day per household (*58*). It was found that automobile travel reductions resulted from modal switching rather than a reduction in trips (*57*-*58*).

Trip destinations and land use mixing, rather than trip origin densities, may be more significant determinants of travel behavior (*51, 53*). Destination density, especially of employment locations, has been found to significantly impact the decision to walk, use transit or carpool (*48, 59*). The layout of transportation facilities and services also impact travel behavior where transit availability (*48, 52*) and street network design and intersection densities (*48, 60*) have been found to enable or prohibit the use of non-automobile modes. Increases in lane mileage were found to increase driving rates (*2*), consistent with the cycle of induced travel (*30*).

Socioeconomic Factors

Diverse interrelated socioeconomic factors also affect travel decisions (*48-49*). Age, particularly as it relates to life-cycle stage (e.g. with or without children; working or retired) has a strong impact on travel behavior. Driving increases with age and with children but then declines when children move out of the home, and continues to decline throughout the remainder of one's life (*61-62*). Driving rates have historically varied based on sex but, in the 1980's, a lack of clarity regarding increases in female driving rates limited the ability to project future driving patterns (*63*). By 1991, however, it was determined that the transition in sex structure of drivers had been completed and that increases in female drivers were no longer a significant cause of overall driving increases (*4*).

Household income has a multidimensional impact since income is a key determinant in residential sorting (*64*) that can impact neighborhood location and type and, as a result, calls into play all the previously-discussed built environment factors that impact travel behavior. Once residential sorting has occurred, income restricts the ability to choose from available modal options and thus impacts travel behaviors (*61, 64*). Income also affects the ability to own a vehicle, however once the initial investments in automobile travel have been made (through purchase, licensing/registration and insurance) people are more likely to drive despite marginal increases in driving costs (*65*, 66). As a result, more available automobiles per household result in a greater proportion of trips taken by automobile (*67*). Conversely, lower vehicle ownership levels in dense, mixed-use environments that allow for modal shifts reduce automobile trips (*67*). Contrary to peak car travel indicators, some researchers (*68*) predicted a 31% increase in vehicles per household in the U.S. from 2000 to 2025 with associated driving increases to be expected. As Lave points out in 1991(*4*), however, only one automobile can be driven at a time such that once ownership saturation occurs, increasing numbers of automobiles would no longer result in increased driving. The complex relationship between automobile availability and driving behavior highlights one of the challenges of explaining and predicting travel behavior.

SEEKING EXPLANATIONS FOR THE TREND REVERSALS

The peak and ensuing decline of vehicle travel per capita has left many questions regarding the cause behind this historic trend reversal, whether it is permanent or temporary in nature, and how vehicle travel interrelates with economic conditions, all of which challenge the ability to predict future travel behavior (*9, 11, 16, 40, 49, 69*). Recalling the research that was done during the vehicle travel growth era, researchers are now analyzing the factors that impact vehicle travel in order to isolate the factor(s) that are causing the peak car travel phenomenon.

Economy, Fuel Prices and Travel Costs

As a result of the complex relationship between vehicle travel, gas prices and economic growth, the economic downturn of 2008 and spike in oil prices may appear to be a reasonable explanation of recent vehicle travel trends. The vehicle travel plateau and decline, however, began prior to these events (*11, 19, 40-41, 44*). Research has found that fuel price fluctuations did have some impacts on travel behavior, but the effects were mostly short-term and cyclical in nature and unrelated to the foundational, big-picture changes to vehicle travel currently taking place (*9, 15*). After factoring in improved fuel economy, the real fuel costs of driving in 2008 were well below the costs to drive during the gas price spike in the 1980's (*24, 49*). This suggests that recent vehicle travel decreases are occurring despite lower fuel costs when compared to the 1980's and that other factors are responsible for driving reductions.

Population Aging

Some portion of vehicle travel decreases may be caused by people progressing through life-cycles that demand different levels of driving (*19, 37, 62, 70*). Retirement, for example, reduces driving with each terminated automobile commute and also as retirees relocate to city centers or retirement communities that enable reduced driving (*12)*. Life-cycle components are impacted by generational variations and, despite retirement-associated travel reductions, the elderly are now driving more than prior generations and represented the largest group of licensed drivers in 2008 (*71*). Even though population aging has negative impacts on vehicle travel internationally (*19*), only a small portion of the decline has been related to aging (*12, 15*) and aging is not a reasonable explanation for many cities that are becoming demographically younger and still seeing reduced vehicle travel (*72*).

Preference Shifts

Modal switching is a potential contributor to reduced driving rates (*19*). After decades of declining modal shares, transit, biking and walking have stabilized or even increased (*15, 37, 40, 49*). Modal switching can cause an exponential "Transit Leverage Effect" that reduces vehicle travel by 3-7 passenger kilometers for each additional passenger kilometer of transit travel (*73*). Driving reductions could be even larger if it were not for the "car left home" phenomenon where commuter shifts to non-automobile modes frees up a vehicle at home and results in 45% new non-work vehicle travel (*74-75*). While modal switching is reducing overall automobile travel, the peak car travel phenomenon is not only being experienced in cities with highly-developed multimodal systems but also occurring in metropolitan areas lacking major transit systems such as Oklahoma City and Indianapolis (*9*).

Shifting preferences has resulted in a "growing culture of urbanism," especially among young adults who are choosing cities over suburbs and multimodalism over automobiles, bucking decades-old trends (*9, 12, 16, 19, 37, 72, 76*). This shift reflects declining value and social status that young people place in automobile culture and the suburban lifestyle (*19*). It has caused a 17.8% drop in licenses among young adults in the U.S. from 1983 to 2010 (*77*), representing the largest driving reduction of any age group (*70*). The shift in the automobile's position as a status symbol is based on demographic and income factors where higher education attainment (*78*) and higher incomes (*79*) correspond with reduced preferences for automobiles, fewer vehicles per household and reduced driving. Household vehicle ownership and use were still found to increase among lower income and less-educated cohorts, suggesting that the private automobiles remain a status symbol for those groups (*78-79*).

The decline of young drivers is occurring worldwide and suggests that this shift is less regional in scope and more fundamental in nature (*15-16, 43, 71*). It is possible that these driving behavior changes are not preferences at all but rather reflections of economic constraints and life-cycle changes for young people (*19, 80-81*). Young adults may be driving less due to the high entry costs of automobiles, especially of insurance rates for new drivers, in combination with lower incomes or unemployment (*37, 71*). In addition, driving rates associated with certain life-cycle stages (*62*) could be delayed through the increased pursuit of college educations and increased age of starting a family, both of which reduce or delay vehicle travel per capita (*19, 72, 81*). Since young people are learning to meet their needs through non-automobile means, there is the potential they will drive less even as they advance through life-cycle stages typically associated with high driving rates (*67*).

For young people, information communication technologies (ICT) such as the iPhone may have surpassed the automobile as a status symbol and replaced the need for face-to-face interaction, reducing physical travel (*19, 72, 80-81*). Though ICT may be a factor in reduced driving among young populations, the ICT revolution occurred after peak car travel was first observed, therefore its contribution to the decline of young drivers does not appear significant (*72*). The impact of ICT on travel behavior, regardless of age cohort, is complex and sometimes contradictory (82-83). Substitution effects may occur but are limited to certain types of trips (*84*) and may actually cause increased overall travel (*82*). For example, the rise of e-shopping may reduce required shopping trips but those trips are replaced with new leisure travel trips (*82*). Prior to peak car travel, it was predicted that both ICT and vehicle travel would continue to grow complementary with each other (*85*). In seeking the potential causal relationship between ICT and peak car travel, Dutch researchers explored the role of e-commerce and found only a marginal connection between business-to-consumer online commerce and reductions in driving (*83*). Oppositely, the rise of consumer-to-consumer online commerce, such as eBay and similar websites, has actually served to increase automobile travel (*83*).

With respect to environmental preferences as it relates to climate change and negative externalities of automobile travel, people with higher levels of environmental awareness were found to have stronger connections between their level of concern and their travel behavior; switching to non-automobile modes or traveling less when possible (*86-88*). Oppositely, however, it has been found that many people with a basic awareness of global warming have a weak understanding of how their travel behavior relates to global warming, and therefore do not alter their driving habits based on such concerns (*86*). Overall, among people using non-automobile modes, environmental concern explained only 14% of users' rationales for riding transit (*89*). Therefore, there must be other factors at play that impact the choice to travel via non-automobile modes other than environmental concern.

Saturation Point / Hitting the Marchetti Wall

Some have postulated that peak car travel is evidence that we have reached the saturation point for the number of daily activities and associated private automobile travel (*11, 23, 41, 90*) and for vehicle ownership (*4, 15, 24*). A related, but slightly more complex explanation of peak car travel is that we have "hit the Marchetti wall" (*12, 91*). The Marchetti Constant refers to the observation that transportation users are inherently limited by time constraints and that, over history, the mean daily travel time per person has hovered around an hour regardless of mode, city size or travel speed (*91-92*). With increasing congestion levels slowing automobile speeds (*17*), the distances that can be reached within the one-hour-a-day constant is reduced as well (*37*). It has been pointed out that in England congestion levels have remained relatively constant while vehicle travel has still decreased so the connection between congestion-based saturation and travel reductions are not clear (*41*)

The Marchetti Constant also applies to city building, finding that cities reach their geographic size limits (they "hit the wall") when all the areas accessible within a half hour by available transport modes have been utilized and inhabited (*91, 93*). It is hypothesized that cities have now reached this travel time-related growth limit where current driving is in equilibrium with land use patterns and will remain in this equilibrium state until a major change occurs in either land use or transportation (*12, 40*). Had downtowns retained their central role in metropolitan regions, the automobile may have hit the Marchetti wall a half-century ago but the spatial decentralization of uses allowed for increased driving and delayed congestion increases (*94*), buying more time for the automobile-oriented city to expand and associated personal vehicle travel to increase.

DISCUSSION AND CONCLUSION

Though peak car travel appears to have begun in 2004, the phenomenon has only recently been identified and acknowledged (*9*, *11-13, 16, 37, 49*). There were some initial assumptions that peak car travel was related to record-high gas prices and the economic recession (*12*) however those factors were determined to have occurred too late to be the primary causes (*9*, *15*). Potential explanations for peak car travel include: 1) saturation of driving demand (*4, 11, 23, 41, 90*); 2) population aging (*19, 37, 70*); 3) switching to non-automobile modes (*12*, *15*, *19*, *37*, *40*); 4) preferences shifts from suburban to urban lifestyles, especially among young adults (*16*, *19*, *37*, *76*); 5) decline of young drivers due to rising costs and delayed life-cycle progression (*15-16*, *19*, *43*, *71*, *80-81*);and 6) that we have "hit the Marchetti wall" in the amount of travel we can accomplish within an hour of traveling per day (*12*, *40*).

To meet assumed growth in vehicle travel demand, transportation planners repeatedly expanded highway systems but the additional supply enabled decades of vehicle travel per capita growth to occur (*2*, *30*). Despite new highway construction and additional travel lanes, vehicle travel growth far outpaced increases in lane-mile capacity (*95*). This provides evidence that no one particular factor was responsible for historic vehicle travel growth and highlights the fact that there is no one specific reason why peak car travel is occurring (*69*). Despite being an international phenomenon (*22-24*) and having a variety of hypothesized causes which only partially explain the phenomenon, the specific causes of peak car travel are not clearly identified (*11*, *20, 23, 40*). As a result, predictions for the future are even harder to determine; highlighting the limitations of vehicle travel-based transportation planning mechanisms. Some have suggested that this is the permanent end of the vehicle travel growth era (*22, 37*) while others state that this could be merely a lag time such that, as the economy improves, vehicle travel growth will also rebound (*15-17*). Demographic, social and economic trends may continue to reduce per capita driving (*23, 49*) but there are still many unknowns regarding how increased wealth and improved fuel technologies will impact travel rates (*41*).

Vehicle travel reductions are combining with increased fuel efficiencies to reduce funding necessary to maintain the current system (*9*). Since driving rates are strongly tied to revenue and to funding allocation, dramatic changes are already needed to address the economic sustainability of our transportation system (*9, 16*). If driving levels hold steady or decrease further, highway subsidies would need to substantially increase under the current funding structure. As a result, we now sit at a time of tremendous opportunity to revise the way we approach transportation planning, from measuring travel and managing budgets to designing and building systems that create both economic and environmental sustainability. The current reversal in the trajectory of driving may indicate a need to shift away from automobile travel-based, predict-and-provide approaches and towards innovative and more dynamic approaches to modeling and planning transportation systems that reflect changing demands (*14*, *16*). At this point, however, accurate travel demand projections cannot be determined since there is still no clearly-identified cause to the peak car travel phenomenon and no indication about whether it is a temporary or permanent occurrence. In addition, there is no definitive rationale why, after decades of simultaneous growth, the apparent relationship between vehicle travel and the economy is now changing so dramatically that it could represent a decoupling of the two variables (*19*-*20*). Only by determining the causes of peak car travel and better understanding the relationship between vehicle travel and the economy can future travel demand be accurately predicted, transportation policies be appropriately conceived and ensuing system enhancements be appropriately funded.

REFERENCES

1. Lee, D.B., L.A. Klein, and G. Camus. Induced traffic and induced demand. In *Transportation Research Record: Journal of the Transportation Research Board (TRB), No.1659*, TRB of the National Academies, Washington, D.C., 1999, pp.68-75.
2. Noland, R.B., and W.A. Cowart. Analysis of metropolitan highway capacity and the growth of vehicle miles of travel. *Transportation*, Vol.27, No.4, 2000, pp.363-390.
3. Goodwin, P.B. Empirical evidence on induced traffic. *Transportation*, Vol.23, No.1, 1996, pp.35-54.
4. Lave, C. *Things won't get a lot worse: The future of U.S. traffic congestion, Working Paper No. 33*. University of California Transportation Center. http://escholarship.org/uc/item/83845860. Accessed October 26, 2013.
5. USDOT, FHWA. Annual vehicle-miles of travel, by vehicle type and highway category, 1936-1995, Table VM-201. 2011. http://www.fhwa.dot.gov/ohim/summary95/section5.html. Accessed November 7, 2013.
6. USDOT, FHWA. Annual vehicle distance traveled in miles and related data, by highway category and vehicle type, Tables VM-1, 1996-2011. 2013. http://www.fhwa.dot.gov/policyinformation/statistics.cfm. Accessed November 7, 2013.
7. U.S. Census Bureau. *Population Estimates: Historical Data: 1900-1999, 2000-2010, 2011*. 2012. http://www.census.gov/popest/data/historical/. Accessed November 7, 2013.
8. U.S. Department of Commerce, Bureau of Economic Analysis. Current-dollar and "real" GDP." 2012. http://www.bea.gov/national/index.htm#gdp. Accessed November 7, 2013.
9. Puentes, R. and A. Tomer. *The Road Less Traveled: An Analysis of Vehicle Miles Traveled Trends in the U.S.* Brookings Institute, Washington, D.C., 2008.
10. Davis, S.C., S.W. Diegal, and R.G. Boundy, for the U.S. Department of Energy. *Transportation Energy Data Book: Edition 31*. Vehicle Technologies Program, Office of Energy Efficiency and Renewable Energy, 2012. cta.ornl.gov/data. Accessed July 28, 2013.
11. Millard-Ball, A., and L. Schipper. Are we reaching peak travel? Trends in passenger transport in eight industrialized countries. *Transport Reviews*, Vol.31, No.3, 2011, pp.357-378.
12. Newman, P., and J. Kenworthy. 'Peak Car Use': Understanding the Demise of Automobile Dependence. *World Transport, Policy & Practice*, Vol.17, No.2, 2011, pp.31-42.
13. Goodwin, P., and K. Van Dender. 'Peak Car' – Themes and Issues. *Transport Reviews*, Vol.33, No.3, 2013, pp.243-254.
14. Metz, D. Peak car and beyond: The fourth era of travel. *Transport Reviews*, Vol.33, No.3, 2013, pp.255-270.
15. Madre, J. L., Y.D. Bussière, R. Collet, and I.T. Villareal. *Are we heading towards a reversal of the trend for ever-greater mobility?* Discussion Papers 2012-16, International Transport Forum, OECD Publishing, 2012. http://www.internationaltransportforum.org/jtrc/DiscussionPapers/DP201216.pdf. Accessed April 28, 2013.
16. Miller, R.E. President's Message. *Institute of Transportation Engineers ITE Journal*, Vol.82, No.8, 2012, p.6.
17. Schrank, D., W. Eisele, and T. Lomax. 2012 Urban Mobility Report: Powered by INRIX Traffic Data. Texas Transportation Institute at the Texas A&M University System, 2011. http://mobility.tamu.edu/ums/report/. Accessed October 21, 2013.
18. USDOT, FHWA. *Traffic volume trends: August 2013*. 2013. https://www.fhwa.dot.gov/policyinformation/travel_monitoring/tvt.cfm. Accessed October 26, 2013.
19. Van Dender, K., and M. Clever. *New Recent Trends in Car Usage in Advanced Economies – Slower Growth Ahead? Discussion Paper No. 2013-09*, International Transport Forum, OECD,

2013. http://www.internationaltransportforum.org/jtrc/DiscussionPapers/jtrcpapers.html . Accessed May 15, 2013.
20. Ecola, L., and M. Wachs. *Exploring the Relationship between Travel Demand and Economic Growth.* FHWA, 2012. http://www.fhwa.dot.gov/policy/otps/pubs/vmt_gdp/index.cfm . Accessed May 7, 2013.
21. Battelle Memorial Institute. *Forecasts of Economic Variables that Impact Passenger and Freight Demand and the Implication of Alternative Economic Assumptions on Modal Travel Demand*, 2007. http://transportationfortomorrow.com/final_report/pdf/volume_3/technical_issue_papers/paper4b_06.pdf. Accessed Oct. 26, 2011.
22. Metz, D. Demographic determinants of daily travel demand. *Transport Policy,* Vol.21, 2012, pp.20-25.
23. Cohen, M.J. The future of automobile society: a socio-technical transitions perspective. *Technology Analysis & Strategic Management,* Vol.24, No.4, 2012, pp.377-390.
24. Schipper, L. Automobile use, fuel economy and CO2 emissions in industrialized countries: Encouraging trends through 2008? *Transport Policy*, Vol.18, No.2, 2011, pp.358–372.
25. U.S. Department of Transportation (USDOT), FHWA. *Provisions governing the allocation of federal funds for highway purposes, Table F-106*. 2008. http://www.fhwa.dot.gov/policyinformation/motorfuel/hwytaxes/2008/ . Accessed May 7, 2013.
26. USDOT, FHWA. *Provisions governing the disposition of state motor-fuel tax receipts, Table MF-106*. 2008. http://www.fhwa.dot.gov/policyinformation/motorfuel/hwytaxes/2008/ . Accessed May 7, 2013.
27. U.S. Energy Information Administration. *Annual Energy Outlook 2013*. U.S Department of Energy, Washington, D.C, 2013. http://www.eia.gov/forecasts/aeo/. Accessed July 23, 2012.
28. McMullen, B.S., and N. Eckstein. The relationship between vehicle miles traveled and economic activity. In *Transportation Research Record: Journal of the TRB, No.2297*, TRB of the National Academies, Washington, D.C., 2012, pp.21-28.
29. Pozdena, R.J. *Driving the Economy: Automotive Travel, Economic Growth and the Risks of Global Warming Regulations.* Cascade Policy Institute, 2009. http://cascadepolicy.org/pdf/VMT%20102109.pdf. Accessed Nov. 2, 2011.
30. Ewing, R., K. Bartholomew, S. Winkelman, J.Walters, and D. Chen. *Growing Cooler: The Evidence on Urban Development and Climate Change.* Urban Land Institute, Washington, D.C., 2008.
31. Liddle, B. The systemic, long-run relation among gasoline demand, gasoline price, income, and vehicle ownership in OECD countries: Evidence from panel cointegration and causality modeling. *Transportation Research Part D: Transport and Environment,* Vol.17, No.4, 2012, pp.327-331.
32. Arnott, R., and K. Small. The economics of traffic congestion. *American Scientist,* Vol.82, No.5, 1994, pp.446-455.
33. Downs, A. *Still Stuck in Traffic: Coping with Peak-Hour Traffic Congestion (Revised).* Brookings Institution, Washington, D.C., 2004.
34. INRIX. Key Findings: *2012-2013 INRIX National Traffic Scorecard Annual Report*, 2013. http://scorecard.inrix.com/scorecard/summary.asp. Accessed April 28, 2013.
35. USDOT, FHWA. *2011 Urban Congestion Trends: Improving Travel Reliability with Operations.* 2012. http://www.ops.fhwa.dot.gov/publications/fhwahop12019/fhwahop12019.pdf. Accessed April 28, 2013.
36. Moore, A.T., S.R. Staley, and R.W. Poole. The role of VMT reduction in meeting climate change policy goals. *Transportation Research Part A: Policy & Practice*, Vol.44, No.8, 2010, pp.565-574.

37. Litman, T. Changing travel demand: Implications for transport planning. *Institute of Transportation Engineers: ITE Journal,* Vol.76, No.9, 2006, pp.27-33.
38. Polzin, S.E., X. Chu, and L. Toole-Holt. Forecasts of future vehicle miles of travel in the United States. In *Transportation Research Record: Journal of the TRB, No.1895,* TRB of the National Academies, Washington, D.C., 2004, pp.147-155.
39. Garceau, T., C. Atkinson-Palombo, N. Garrick, J. Outlaw, J., C. McCahill, and H. Ahangari. Evaluating selected costs of automobile-oriented transportation systems from a sustainability perspective. *Research in Transportation Business & Management*, Vol.7, 2013, pp.43-53.
40. Lucas, K., and Jones, P. *The Car in British Society: Trends and Challenges*. The RAC Foundation, London, UK, 2009.
41. Metz, D. Saturation of demand for daily travel. *Transport Reviews,* Vol.30, No.5, 2010, pp.659-674.
42. Stanley, J., and S. Barrett. *Moving People – Solutions for a Growing Australia*. Report for Australasian Railway Association, Bus Industry Confederation and International Association of Public Transport, 2010. http://apo.org.au/research/moving-people-solutions-growing-australia. Accessed July 25, 2013.
43. Kuhnimhof, T., M. Wirtz, and W. Manz. Decomposing Young Germans' Altered Car Use Patterns Lower Incomes, More Students, Decrease in Car Travel by Men, and More Multimodality. In *Transportation Research Record: Journal of the TRB, No.2023,* TRB of the National Academies, Washington, D.C., 2012, pp.64-71.
44. Kienitz, R. *Transportation in the United States: New Trends and Implications for China* (PowerPoint presentation). 2012. http://beijingenergynetwork.com/wp-content/uploads/2013/02/transportationintheusandchinajune2012version2-120619033442-phpapp02.pdf. Accessed April 28, 2013.
45. Cervero, R., and K. Kockelman. Travel demand and the 3Ds: Density, diversity, and design. *Transportation Research D,* Vol.2, No.3, 1997, pp.199–219.
46. Ewing, R., and R. Cervero. Travel and the Built Environment: A Synthesis. In *Transportation Research Record: Journal of the TRB, No.1780,* TRB of the National Academies, Washington, D.C., 2001, pp.87-114.
47. Ewing, R., M.J. Greenwald, M. Zhang, J. Walters, M. Feldman, R. Cervero, and J. Thomas. *Measuring the impact of urban form and transit access on mixed use site trip generation rates—Portland pilot study*. U.S. Environmental Protection Agency, Washington, D.C., 2009.
48. Ewing, R., and R. Cervero. Travel and the Built Environment: A Meta-Analysis. *Journal of the American Planning Association*, Vol.76, No.3, 2010, pp.266-294.
49. Polzin, S.E., prepared for the U.S. Department of Transportation. *The case for moderate growth in vehicle miles of travel: A critical juncture in U.S. travel behavior trends.* Center for Urban Transportation Research, University of South Florida, 2006. http://www.cutr.usf.edu/wp-content/uploads/2012/08/The-Case-for-Moderate-Growth-in-VMT-2006-Final.pdf . Accessed May 18, 2012.
50. TRB. *Special Report 298: Driving and the Built Environment: Effects of Compact Development on Motorized Travel, Energy Use, and CO2 Emissions.* TRB of the National Academies, Washington, D.C., 2009. http://www.trb.org/Publications/Blurbs/162093.aspx. Accessed May 11, 2013.
51. Vernez Moudon, A. and O. Stewart. *Tools for estimating VMT reductions from built environment changes, Report WA-RD 806.3*. 2013. http://www.wsdot.wa.gov/Research/Reports/800/806.3.htm. Accessed October 30, 2013.
52. Schimek, P. Household motor vehicle ownership and use: How much does residential density matter? In *Transportation Research Record: Journal of the TRB, No.1552,* TRB of the National Academies, Washington, D.C., 1996, pp.120-125.

53. Badoe, D.A., and E.J. Miller. Transportation-land-use interaction: empirical findings in North America, and their implications for modeling. *Transportation Research Part D: Transport and Environment*, Vol.5, No.4, 2000, pp.235-263.
54. Kockelman, K.M. Travel behavior as a function of accessibility, land-use mixing, and land-use balance: evidence from the San Francisco bay area. In *Transportation Research Record: Journal of the TRB, No.1607*, TRB of the National Academies, Washington, D.C., 1997, pp.116-125.
55. Messenger, T., and R. Ewing. Transit-oriented development in the Sun Belt. In *Transportation Research Record: Journal of the TRB, No.1552*, TRB of the National Academies, Washington, D.C., 1996, pp.145-153.
56. Krizek, K. Residential relocation and changes in urban travel: does neighborhood scale urban form matter? *Journal of the American Planning Association*, Vol.69, No.3, 2003, pp.265-279.
57. Handy, S. L. Urban Form and Pedestrian Choices: Study of Austin Neighborhoods. In *Transportation Research Record: Journal of the TRB, No.1552*, TRB of the National Academies, Washington, D.C., 1996, pp.135-144.
58. Khattak, A.J., and D. Rodriguez, D. Travel behavior in neo-traditional neighborhood developments: A case study in USA. *Transportation Research Part A: Policy and Practice*, Vol.39, No.6, 2005, pp.481-500.
59. Frank, L.D., and G. Pivo. Impacts of mixed use and density on utilization of three modes of travel: single-occupant vehicle, transit and walking. In *Transportation Research Record: Journal of the TRB, No.1466*, TRB of the National Academies, Washington, D.C., 1994, pp.44-52.
60. Marshall, W.E. and N.W. Garrick. Effect of Street Network Design on Walking and Biking. In *Transportation Research Record: Journal of the TRB, No.2198*, TRB of the National Academies, Washington, D.C., 2010, pp.103-115.
61. Rentziou, A., K. Gkritza, and R.R. Souleyrette. VMT, energy consumption, and GHG emissions forecasting for passenger transportation. *Transportation Research A: Policy and Practice*, Vol. 46, No.3, 2012, pp.487-500.
62. Zimmerman, C. The life-cycle concept as a tool for travel research. *Transportation*, Vol.11, No.1, 1982, pp.51-69.
63. Greene, D.L. Long-run vehicle travel prediction from demographic trends. In *Transportation Research Record: Journal of the TRB, No. 1135*, TRB of the National Academies, Washington, D.C., 1987, pp.1-9.
64. Bhat, C.R., and J.Y. Guo. A comprehensive analysis of built environment characteristics on household residential choice and auto ownership levels. *Transportation Research Part B: Methodological*, Vol.41, No.5, 2007, pp.506-526.
65. Banister, D. Influence of habit formation on modal choice – heuristic model. *Transportation*, Vol.7, No.1, 1978, pp.5-18.
66. Burbank, C.J. and P. Brinckerhoff. *Strategies for Reducing the Impacts of Surface Transportation on Global Climate Change: A Synthesis of Policy Research and State and Local Mitigation Strategies*. National Highway Cooperative Research Program Project, 20-24(59). AASHTO, 2009. http://climatechange.transportation.org/pdf/nchrp_2024_59_final_report_031309.pdf. Accessed March 5, 2012.
67. Weinberger, R., and F. Goetzke. Unpacking Preference: How Previous Experience Affects Auto Ownership in the United States. *Urban Studies*, Vol.47, No.10, 2010, pp. 2111-2128.
68. Feng, Q.S., Z.L. Wang, D.A. Gu, and Y. Zeng. Household vehicle consumption forecasts in the United States, 2000 to 2025. *International Journal of Market Research*, Vol.53, No.5, 2011, pp.593-618.
69. Stokes, G. The prospects for future levels of car access and use. *Transport Reviews*, Vol.33, No.3, 2013, pp.360-375.

70. Kuhnimhof, T., D. Zumkeller, and B. Chlond. Who made peak car, and how? A breakdown of trends over four decades in four countries. *Transport Reviews* , Vol.33, No.3, 2013, pp.325-342.
71. Sivak, M. and B. Schoettle. Recent Changes in the Age Composition of U.S. Drivers: Implications for the Extent, Safety, and Environmental Consequences of Personal Transportation. *Traffic Injury Prevention*, Vol.12, No.6, 2011, pp.*588*-592.
72. Kuhnimhof, T., J. Armoogum, R. Buehler, J. Dargay, J.M. Denstadli, and T. Yamamoto. Men Shape a Downward Trend in Car Use among Young Adults—Evidence from Six Industrialized Countries. *Transport Reviews,* Vol.32, No.6, 2012, pp.761-779.
73. Newman, P., J. Kenworthy, and G. Glazebrook. How to create exponential decline in car use in Australian cities. *Australian Planner,* Vol.45, No.3, 2008, pp.17-19.
74. Gross, J.M. *The car left home*. New York Department of Transportation, Planning Division, New York, 1979.
75. Maat, K., and H.J.P. Timmermans. Influence of the residential and work environment on car use in dual-earner households. *Transportation Research Part A – Policy and Practice,* Vol.43, No.7, 2009, pp.654-664.
76. Headicar, P. The changing spatial distribution of the population in England: Its nature and significance for 'peak car.' *Transport Reviews, Vol.33, No.3*, 2013, pp.310-324.
77. Sivak, M. and B. Schoettle. Update: Percentage of young persons with a driver's license continues to drop. *Traffic Injury Prevention,* Vol.13, No.4, 2012, p.341.
78. Goetzke F., and R.Weinberger. Separating contextual from endogenous effects in automobile ownership models. *Environment and Planning A,* Vol.44, No.5, 2012, pp.1032 – 1046.
79. Grimal, R., R. Collet, and J.L. Madre. Is the stagnation of individual car travel a general phenomenon in France? A time-series analysis by zone of residence and standard of living. *Transport Reviews,* Vol.33, No.3, 2013, pp.291-309.
80. Delbosc, A., and G. Currie. Causes of youth licensing decline: A synthesis of evidence. *Transport Reviews* , Vol.33, No.3, 2013, pp.271-290.
81. Van der Waard, J., P. Jorritsma, and B. Immers. New drivers in mobility; what moves the Dutch in 2012? *Transport Reviews,* Vol.33, No.3, 2013, pp.343-359.
82. Crocco, F., L. Eboli, and G. Mazzulla. Individual attitudes and shopping mode characteristics affecting the use of e-shopping and related travel. *Transport and telecommunication*, Vol.14, No.1, 2013, pp.45-56.
83. Weltevreden, J.W.J., and O. Rotem-Mindali. Mobility effects of b2c and c2c e-commerce in the Netherlands: a quantitative assessment. *Journal of Transport Geography*, Vol.17, No.2, 2009, pp.83-92.
84. Andreev, P., I. Salomon, and N. Pliskin. Review: State of teleactivities. *Transportation Research Part C: Emerging Technologies,* Vol.18, No.1, 2010, pp.3-20.
85. Mokhtarian, P.L., and I. Salomon. Emerging travel patterns: Do telecommunications make a difference? In *In perpetual motion: Travel behavior research opportunities and application challenges*. Emerald Group Publishing Limited, U.K., 2002.
86. Anable, J., B. Lane, and T. Kelay, prepared for the UK Department of Transport. *An evidence based review of public attitudes to climate change and transport behaviour*, 2006. www.sts-technology.com/docs/DfT-CC-Report.pdf. Accessed July 23, 2013.
87. Kim, J.H., Y.K. Bae, and J.H. Chung. Effects of personal proenvironmental attitudes on mode choice behavior: New ecofriendly water transit system in Seoul, South Korea. In *Transportation Research Record: Journal of the TRB, No.2274*, TRB of the National Academies, Washington, D.C., 2012, pp.175-183.
88. Steg, L., and I. Sievers. Cultural theory and individual perceptions of environmental risks. *Environment and behavior,* Vol.32, No.2, 2000, pp.250-269.
89. Gardner, B. and C. Abraham. Going green? Modeling the impact of environmental concerns and perceptions of transportation alternatives on decisions to drive. *Journal of Applied Social Psychology,* Vol.40, No.4, 2010, pp.831-849.

90. Crozet, Y. *The Prospects for Inter-Urban Travel Demand.* Discussion Paper 2009-14. International Transport Forum, 2009. http://www.internationaltransportforum.org/jtrc/DiscussionPapers/jtrcpapers.html . Accessed May 11, 2013.
91. Marchetti, C. Anthropological invariants in travel behavior. *Technological Forecasting and Social Change*, Vol.47, No.1, 1994, pp.75-88.
92. Schafer, A., and D. Victor. The future mobility of the world population. *Transportation Research Part A: Policy and Practice,* Vol. 34, No.3, 2000, pp.171-205.
93. Newman, P., and J. Kenworthy. *Sustainability and Cities: Overcoming Automobile Dependence*. Island Press, Washington, D.C., 1999.
94. Gordon, P., A. Kumar, and H.W. Richardson. Congestion, changing metropolitan structure and city size in the United States. *International Regional Science Review*, Vol. 12, No.1, pp.45-56.
95. Parry, I.W.H., M. Walls, and W. Harrington. Automobile Externalities and Policies. *Journal of Economic Literature*, Vol. 45, No.2, 2007, pp.373-399.

CHAPTER 3: PEAK CAR TRAVEL IN THE UNITED STATES: A TWO-DECADE LONG PHENOMENON AT THE STATE LEVEL

Published Work:
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ABSTRACT

Peak car travel is an international phenomenon that became evident at the national scale in the United States (U.S.) in 2004. In addition and potentially related to peak car travel is the decoupling of economic growth from driving levels. While a wealth of literature has addressed these phenomena at the national scale both for the U.S. and in other developed countries, few studies have been undertaken at other geographic scales, especially at the statewide scale in the U.S. This study investigates state-level driving and economic patterns from 1980 to 2011 to understand changes that are occurring. The research determined that peak car travel first occurred at the state level as early as 1992 in Washington State while another 10 states peaked as of 2000. By 2011, 48 of the 50 states had peaked. The longevity of this phenomenon at the state level provides evidence that peak car travel in the U.S. is a more permanent phenomenon than previously thought. In addition, the decoupling of economic growth from driving is evident at the state level. In the 1980's, these indicators were positively-correlated at the state level. A significant change occurred by the 2000's, however, as any significant connection ceased for the majority of states. For four of the earliest peak car travel states, the relationship between economic growth and driving turned negative. This shows that driving decreases are not associated with negative economic consequences. Rather, in several states, driving reductions are now associated with increased, rather than decreased, economic growth.

INTRODUCTION

The economic impacts of global warming, estimated to cost 1-2% of the global output each year (*1*) have compelled some policy leaders to develop greenhouse gas (GHG)-reduction plans in order to stabilize emissions levels and stave off the worst impacts of climate change. Since the transportation sector accounts for 37% of emissions in the United States (U.S.), numerous strategies target transportation-related emissions (*2*). Many plans incorporate strategies to reduce vehicle-miles traveled (VMT) since 29% of overall U.S. emissions are "tailpipe emissions" associated with high levels of driving (*2-4*). VMT-reduction strategies have not been universally-welcome, however, with opposition organized around the perception of a positive relationship with economic growth and the assumption that any attempt to reduce driving will have negative consequences (*5-7*). At the very least, some have identified that we really do not know the consequences of such an approach (*8*) and therefore recommend prioritizing other GHG-reduction strategies instead (*9*).

For nearly a century, personal wealth (measured by Gross Domestic Product, GDP, per capita) grew simultaneously with personal driving levels (measured by VMT per capita) reflecting the complex, bi-directional relationship between the two variables (*10-11*). Other than a few shocks from energy crises, driving levels continued their upward trend, leading many to expect and to plan for continued record growth (*12-13*). In 2004, and only identified several years later, driving levels in the U.S. seemed to peak and then decline (*14-15*). This phenomenon is referred to as "peak car" (*14,16*), "peak travel" (*17-18*) and, in this article, "peak car travel." Simultaneous with this revolutionary trend reversal is the apparent weakening or decoupling of driving levels from prosperity indicators such that economic growth is now occurring without a return to record increases in driving (*18-19*). This decoupling suggests that, despite prevailing concerns, the economy may now be able to grow without commensurate increases in driving.

To date, there have been few analyses of these trend reversals at the state level in the U.S. Puentes & Tomer (*12*) are the only researchers to have identified peak car travel patterns at the state level;

highlighting that overall VMT totals peaked in 48 states as of 2008. In addition to the statewide scale, their report effectively showed that peak car travel has occurred at multi-state and metropolitan scales. The report's breadth of analysis, however, occurs at the expense of depth for any one particular scale and of the ability to analyze year-to-year changes. Litman (*20*) also incorporated but did not focus on state-level data in a cross-sectional analysis of GDP per capita and VMT per capita. Using 2004-2006 data, he found that wealth levels tended to decrease as driving levels increase (R-Square 0.29). Kooshian & Winkelman (*21*), using 2008 data, found a similar result between the two variables. Together, their analyses provide a snapshot of how the two variables related in the mid-2000's. However, no studies have examined how this relationship has evolved at the state level over time, especially in the context of peak car travel.

This research takes a two-step approach in order to address the notable gaps in state-level analysis as they relate to peak car travel and the decoupling of driving from economic growth. The first step is to review driving levels at the state level from 1980 to 2011 to quantify when peak car travel occurred for individual states. The second step is to identify whether a statistically-significant relationship exists between driving levels and the economy at the state level and analyze how these vary from state to state and from one decade to another.

BACKGROUND / LITERATURE REVIEW

Peak Car Travel

Driving levels in the U.S. increased steadily for a century, leading many transportation planners and federal agencies to predict continued increases (*22).* In 2004, however, VMT per capita in the U.S. peaked at 10,117 and then declined slightly in ensuing years (*12,14-15,17*). The peak car travel phenomenon is occurring internationally across the developed world (*18,23-27*) and has some questioning if this radical deviation represents a new era of travel behavior (*28*).

Due to the rank similarities of peak car travel patterns from one country to another despite very different urban layouts, densities and demographics, some have suggested that a structural or fundamental change is the cause of peak car travel rather than changes specific to any one country (*17,29*). Despite the widespread occurrence, the reasons for peak car travel are still not clear (17,23-24) though various potential explanations include: saturation of driving demand (*18-19,23*); population aging (*15,30*); modal-switching (*14-15,25,27,30*); hitting "the Marchetti wall" in the potential amount of travel each day (*14,27,30*); decline of young drivers due to rising costs and delayed life-cycle progression (*15,25,31*); and preference shifts towards urban lifestyles (*15,26,30,32*). Though some of these reasons may explain driving reductions in specific places, there is no one reason or combination of reasons held in common across geographies that explains why peak car travel is occurring in a diversity of places with dramatically different urban layouts, demographics and economic conditions (*17*). As a result, the specific cause(s) of peak car travel have yet to be identified (*12,15,17-18*).

Information communication technologies (ICT) are most likely impacting travel behaviors as well; removing information barriers to using non-car modes and car-share programs as well as reducing the need for face-to-face contact (*33*). A 2013 U.S. Public Interest Research Group (PIRG; *33*) report provided compelling evidence of the technological revolution and its potential for revolutionizing travel behavior. Comparing 2000 to 2012 ICT indicators, PIRG found a jump in internet use (46% to 82%), a rise in cell phone ownership (53% to 88%), a dramatic increase in internet access (5% to 72%) and a proliferation of smart phone devices (0% to 46%; *33*). Despite PIRG's evidence, the impact of ICT is still vague and some have suggested that the role of ICT is being overestimated at the expense of understanding the importance of other social factors (*34*). Also, since peak car travel began prior to the recent impacts of ICT, any causal impact of ICT appears to be minimal (*35*).

To date, there has been little analysis of peak car travel patterns in the U.S. at the statewide scale. Puentes and Tomer (*12*) are unique in considering changing driving patterns at regional, state-level and metropolitan scales. They identified that overall VMT peaked nationally in 2006 and had its first decline in 2007. State-level VMT growth patterns reversed during the 2006 to 2008 time period as 45 states posted VMT reductions (*12*). With respect to per capita driving, Puentes & Tomer (*12*) identified that driving levels declined in 15 states from 2002 to 2006 and in 48 states from 2006 to 2008. Though not particularly emphasized, they identified that Washington was the only state with decreased driving levels from 1991 to 2002 (*12*).

While Puentes & Tomer (*12*) analyzed peak car travel patterns within the U.S., their research had some limitations due to the impressive breadth of their geographic analysis. They utilized 2006 as a baseline year for comparing driving indicators to three other years of analysis (1991 2002 and 2008) which overlooked patterns evolving on an annual basis. They focused on overall VMT figures (rather than on VMT per capita which may be a more accurate reflection of driving behavior) which fails to account for other factors impacting VMT totals such as migration patterns during the same time period. While they present VMT per capita data in Table 3 (p.19), per capita driving patterns are not discussed in much detail in their report.

Decoupling of the Economy from Vehicle Travel

The relationship between economic conditions and travel behavior is highly complex and varies based on time, place and scale of analysis. Economic output, often measured using GDP per capita, has experienced concurrent growth with driving levels since VMT data were first available in 1936 (*11*,*13*,*17*). Despite closely-correlated growth (*6*,*10*-*11*), the nature of their relationship is unclear. It has been argued that driving is a normal good in which demand increases while wealth increases thus the causality is from wealth to driving (*10*,*12*) yet travel is an essential input to economic activity so some level of bi-directional causality would be expected (*10*-*11*). Since travel can be achieved through multiple modes, driving reductions should not be assumed to negatively impact GDP levels (*12*). Despite this, reducing VMT to reduce GHG emissions has met resistance among those who believe the economic ramifications of reducing VMT could be devastating (*5*-*6*) or are at least not understood enough to take responsible actions (*7*-*8*). The question about whether VMT reductions would cause economic decline, spur economic growth or have no impact whatsoever is of considerable interest to transportation policy-makers (*11*).

Despite the contested nature of VMT-reduction strategies, driving rates are declining nationally and, equally as notable, without commensurate decreases in GDP per capita. This calls into question the connection between GDP per capita and VMT per capita as their relationship appears to be weakening (*18-19*). The shifting nature of the relationship may have begun as far back as 1982 when strong bi-directional causality ceased and the relationship became highly variable (*10-11,15*). Others have argued that the decoupling began in the mid-1990's when personal income growth outpaced driving growth (*11,21*). While the Great Recession of 2008 has been responsible for some driving reductions (*12,15*), it occurred too late to account for the peak car travel phenomenon (*15,18-19,27*).

As the economy recovers and grows in the U.S. without commensurate growth in driving, the continued assumption of connectivity between driving and the economy appears to be misguided (*17,19*). Driving has been vital to economic growth in the past and remains the dominant mode of transportation in the U.S. (*32*). However, its contribution to economic growth appears to now be declining (*21*). The majority of studies have assessed the decoupling changes at the national level and, to date, only two studies (*20-21*) have done any analysis at the state level. Similar to the approach taken by Puentes & Tomer (*12*) in identifying peak car travel at multiple scales, Litman (*20*) assessed the shifting relationships between the economy and travel behavior at various scales in the U.S. and globally. He provided several analyses at the metropolitan scale and found some positive individual connections of GDP per capita with transit ridership and urban densities. Like Puentes & Tomer (*12*), Litman's breadth of analysis depicted patterns at various scales however it did not go into depth to the statewide scale. With respect to state-level patterns, he found that (using 2004-2006 data) economic output tended to decrease as driving levels increased when comparing the 50 states (R-square 0.29). Kooshian & Winkelman (*21*), found similar results at the state level for 2008 where increased VMT per capita had a weak (R-square 0.22) negative correlation with GDP per capita. Their research provided a snapshot of how the two variables relate at the state level in the mid-2000's however no researchers have looked at how the economy-driving relationship has evolved for individual states over time, especially in the context of peak car travel.

RESEARCH METHODS

The research described here analyzes the driving patterns and relationships between driving and the economy for each of the 50 states in the U.S. The state level of analysis is a critical scale to assess these patterns since, in the U.S., the state is the political unit at which many decisions affecting transportation are made. Many policies that impact travel behavior, economic development and address environmental concerns are often initiated, enabled or implemented at the state level. The lack of research at the state level hinders the ability of state and federal leaders to understand existing and historical conditions in their own jurisdictions as well as identify variations from one state to another. Pursuing a state-based approach will not only serve to expand scholarly knowledge but will also inform policy-makers about past and current patterns in the 50 states in order to appropriately prepare for future needs.

The time period for this research is 1980-2011 with one analysis utilizing annual data and one model consolidating years of data into "decades" (1980-1989; 1990-1999; and 2000-2011) for each state to provide a comparative analysis of trends over three different time periods.

Data

Two main metrics are utilized in this research: VMT per capita and GDP per capita. In order to generate VMT per capita, overall VMT data for each state from 1980-2011 (*36-37*) were divided by state overall population data for the same years (*38-41*). Total GDP data for all industries (*42-43*) were adjusted for inflation to 2011 dollars using the Consumer Price Index for Urban Consumers (*44*). The corrected GDP values were then divided by state populations in order to generate GDP per capita for each year for each state.

Though these data inputs and derived metrics are somewhat crude as measures and have certain limitations, they are prominently-used indicators in the policy field. With respect to driving, VMT is a popular indicator because it is easy to measure, widely-available and easily-transferable across geographies (*11,24*). VMT is also a critical input into transportation planning and funding metrics (*17*).

Transportation funding often relies on fuel tax revenues that are inherently connected to driving levels and vehicle fuel efficiencies (*12*). The simplicity of VMT data results in some limitations such as a failure to account for non-car travel, the inability to estimate congestion and the fact that many externalities of driving are not easily tied to the amount of VMT (*11*). Despite these limitations, VMT figures are still quite telling with respect to car travel.

GDP estimates the market value of goods and services produced in a delineated location in a certain time period (*11*). The use of GDP data has similar benefits and limitations to that of VMT. When analyzing GDP at the "all industries" level, it does not provide information about structural changes within an economy or any indication of changes as they relate to macroeconomic factors. In addition, at such an aggregated scale, the use of GDP fails to address income distribution within an economy and is therefore considered by some to be a poor indicator of individual economic well-being (*11*). Additional challenges arise when considering that overall GDP figures cannot account for a growing level of international business activity (*11*). Despite this, GDP is useful as an indicator because it is easily-measured, easy to understand and has a level of transferability that allows for comparisons across boundaries and scales (*11*).

Using overall state population data to generate VMT per capita and GDP capita provides the ability to estimate how much driving or economic activity is associated with the average person in a state in a particular year. As it relates to VMT, a per capita figure provides a more appropriate look at driving behavior than would considering a state's overall VMT. A state's overall VMT could grow or shrink depending on changes in a state's population. By using VMT per capita, any migration-related changes impacting overall VMT are incorporated into per capita figures. A drawback to using overall population rather than more specific information is that is does not account for demographic changes such as changes in income, age, and life-cycle stage that could impact driving as well. The focus of this research, however, is primarily to identify peak car travel and decoupling patterns among the states. The caveats with respect to VMT, GDP and population data are beyond the scope of this paper and present an opportunity for future research that addresses these limitations, potentially as it relates to explaining the reasons behind peak car travel and associated phenomena.

Methods

This research has two main sections. The first section is the peak car travel analysis. For this, VMT per capita data were analyzed for each state from 1980 to 2011 to identify changes for each state over time as well as for a comparison of states to each other. The record-highest VMT per capita year for each state during the time period was identified as the "peak" driving year unless the highest value occurred in 2011 (the latest year included in the analysis). For those states with a highest value in 2011, it was determined that no peak had occurred since VMT per capita levels were continuing to increase to record levels. Overall patterns of increasing and decreasing driving levels were also analyzed to identify common trends among the states over time. To depict peaking patterns among the states, Figure 2 identifies that have peaked as of four different years: 1992, the first year any state peaked; 1999, the first year with multiple states peaking simultaneously; 2004, the U.S. peak year; and 2011, the last year of data included in the analysis.

The second portion of the research seeks to identify how the relationship between GDP per capita and VMT per capita changed over time at the state level. To accomplish this, a series of three simple linear regressions were performed for each state. For all regressions GDP per capita was the independent variable and VMT per capita was the dependent variable. The first regression model for a state used annual data from 1980 to 1989 to determine if and how the two variables related during that decade for that state. The procedure was then repeated for 1990-1999 and 2000-2011 to determine the nature of the relationship for each of those time periods for each individual state. Upon running all three regression models, we were then able to analyze how the relationship, if present, changed over time for any particular state. Upon running all 150 regressions (3 per state, 50 states), overall patterns of time and geography were analyzed.

RESULTS

Results: Peak Car Travel at State Level

While VMT per capita in the U.S. peaked in 2004, state-level peaks occurred much earlier than that, with Washington as the earliest state to peak in 1992 at 9,610 VMT per capita (see Figure 1 and Table 1). As of 2011, Washington had 8,339 VMT per capita. In total, 48 states have peaked as of 2011 with 40 of those states continuing to decline after their peak and eight states increasing as of 2011 but still well below their record-high peak year. In the same year that Washington peaked, 26 states saw increases of more than 200 VMT per capita as compared to 1991. Another 17 states were experiencing slower growth (0-200 VMT per capita more than prior year) and six states posted decreases that were not directly associated with a peak. Nevada was the second state to peak and did so in 1996 at 10,018 VMT per capita and declined to 7,739 by 2009. It has since turned back up and is 8,882 in 2011; still 1,136 miles lower than in its' peak year. Six more states (Idaho, Kentucky, Missouri, Oregon, Rhode Island and Virginia) peaked in 1999, bringing the number of "past-peak" states to eight by the start of the new millennium. Among the states not at peak by 1999, a general pattern of slower growth becomes evident as only 10 states maintained rapid growth rates (more than 200 VMT per capita higher than 1998) while 27 states posted slower gains of 0-200 VMT per capita as compared to 1998.

Seven more states peaked in the early 2000's (2000: Georgia and Texas; 2002: Alaska and Utah; 2003: Maine, Vermont and Wyoming). Alaska's VMT per capita has declined so much since its peak that 2011 was the state's lowest driving level during the entire time period considered (1980-2011). Eleven states peaked during 2004 which was also the year of the national peak; bringing the total number to 26 states. In 2005, 2006 and 2007, another six, nine and five states, respectively, experienced a peak and ensuing decline in VMT per capita. Mississippi and Indiana were two of the latest states to peak, doing so in 2008 and 2009, respectively.

In 2011, 40 states posted lower VMT per capita than the prior year and, of the 10 states with higher driving levels than in 2010, eight were still well below their record-high peak years. Only Alabama and North Dakota have not seen their per capita driving levels peak as of 2011. Alabama saw a series of temporary dips from 12,853 VMT per capita in 1999 to 12,717 in 2001, and again in from 2007 to 2008, dropping from 13,241 to 12,678 VMT per capita during that time period. It has since returned to record-setting growth, with 13,516 VMT per capita in 2011. Alabama and North Dakota are currently anomalies as both the national and state-level trends reflect lower driving per person. The most recent peak occurred five years ago, while 20% of the states experienced a peak nearly a decade-and-a-half ago. Though the nature of peak car travel as being permanent or temporary is still being questioned, the fact that peak car travel has been occurring since the 1990's at the state level may provide evidence that this is not a temporary phenomenon at all and that peak car travel represents a new era in transportation.

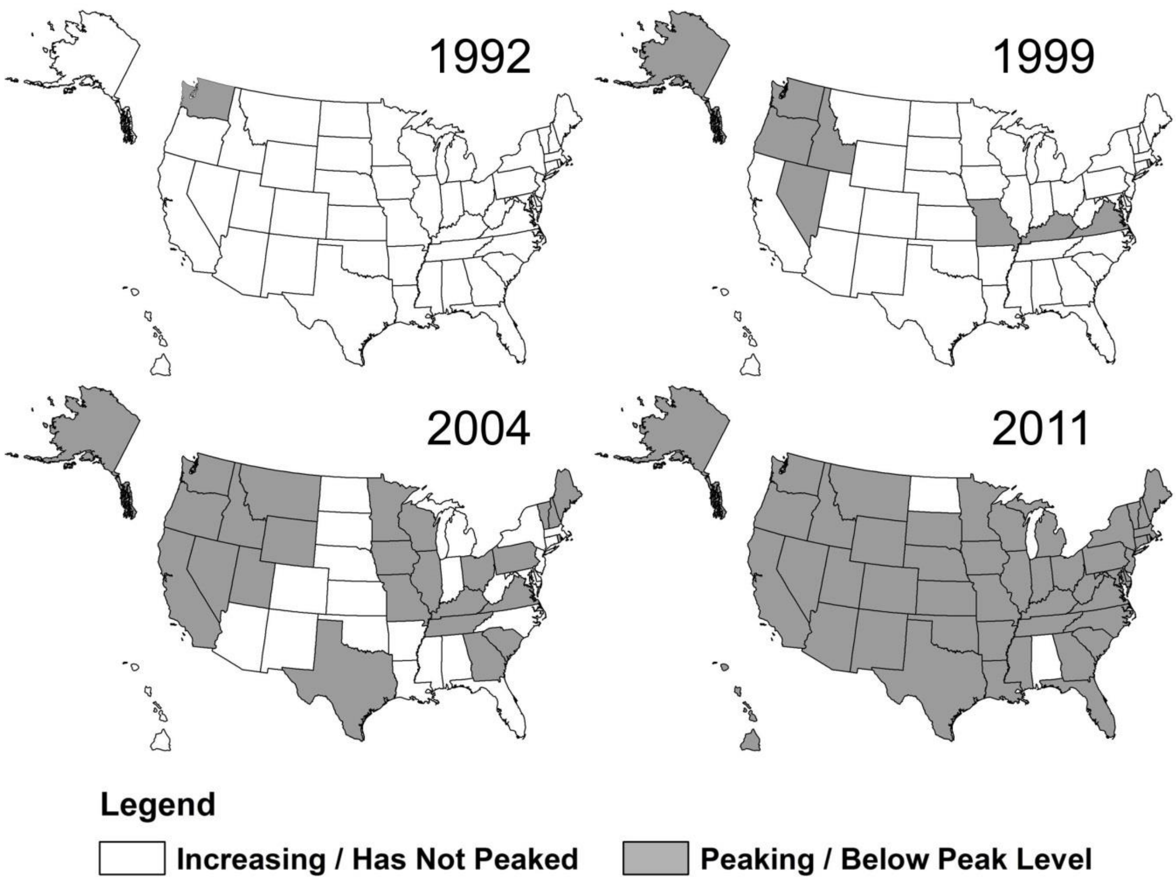

FIGURE 1: Peak car travel at the state level: Changes in driving levels from 1992-2011 (Created by author; base map: *45*).

TABLE 1 Peak Car Travel Patterns and Regression Results (X=Gross Domestic Product Per capita; Y=Vehicle Miles Traveled Per Capita) at the U.S. State Level

		VMT per Capita			GDP per Capita			R-Square (Slope direction)		
State	Peak Year	1980	Peak Year	2011	1980	Peak Year	2011	1980-1989	1990-1999	2000-2011
AL	NA	7,455	NA	13,513	$25,338	NA	$37,173	0.93***(+)	0.96***(+)	0.31* (+)
AK	2002	6,632	7,618	6,345	$103,813	$56,213	$70,895	NS	NS	0.32*(-)
AZ	2006	6,597	10,088	9,212	$30,896	$44,345	$39,489	0.38*(+)	0.34*(+)	0.74***(+)
AR	2006	7,099	11,725	11,214	$30,896	$44,345	$39,489	0.76***(+)	0.98***(+)	0.50***(+)
CA	2004	6,587	9,250	8,512	$37,826	$52,570	$50,647	0.94***(+)	0.69***(+)	NS
CO	2005	7,779	10,291	9,109	$37,826	$54,344	$50,647	0.83***(+)	NS	0.47**(+)
CT	2007	6,246	9,188	8,698	$35,814	$68,780	$62,951	0.97***(+)	0.93***(+)	NS
DE	2005	7,121	11,320	9,941	$36,276	$74,629	$70,967	NS	0.95***(+)	NS
FL	2005	8,106	11,332	10,054	$27,420	$44,119	$39,168	0.34*(+)	0.85***(+)	0.70***(+)
GA	2000	7,905	12,827	11,053	$28,097	$46,906	$42,530	0.83***(+)	0.94***(+)	0.86***(+)
HI	2007	5,789	8,102	7,304	$37,862	$54,449	$50,920	0.90***(+)	0.59***(+)	0.74***(+)
ID	1999	7,355	11,165	10,063	$28,677	$35,339	$36,023	NS	0.66** (+)	NS
IL	2004	5,696	8,630	8,028	$34,704	$51,377	$52,081	0.96***(+)	0.96***(+)	NS
IN	2009	7,047	11,930	11,737	$29,271	$41,215	$43,632	0.73***(+)	0.92***(+)	NS
IA	2004	6,511	10,722	10,207	$32,399	$46,792	$47,695	0.44**(+)	0.92***(+)	NS
KS	2006	7,315	10,965	10,459	$32,682	$45,210	$46,937	0.89***(+)	0.95***(+)	NS
KY	1999	6,893	11,726	11,006	$27,604	$38,713	$38,454	0.93***(+)	0.93***(+)	0.11***(-)
LA	2006	5,805	10,711	10,167	$41,491	$53,794	$51,890	0.39*(-)	0.54**(+)	0.74***(+)
ME	2003	6,638	11,443	10,725	$24,911	$38,942	$39,519	0.99***(+)	0.93***(+)	NS
MD	2005	6,779	10,088	9,628	$30,763	$51,010	$52,361	0.98***(+)	0.83***(+)	NS
MA	2005	6,169	8,594	8,293	$33,158	$57,706	$58,986	0.91***(+)	0.88***(+)	NS
MI	2007	6,700	10,408	9,594	$30,692	$41,736	$38,995	0.85***(+)	0.83***(+)	NS
MN	2004	6,996	11,137	10,601	$33,634	$53,238	$52,384	0.94***(+)	0.92***(+)	0.38**(+)
MS	2008	6,552	14,867	13,048	$23,125	$33,920	$32,746	0.88***(+)	0.84**(+)	0.77***(+)
MO	1999	6,928	12,204	11,448	$29,105	$42,619	$41,517	0.95***(+)	0.98***(+)	NS
MT	2004	8,419	12,104	11,687	$30,970	$35,793	$39,003	0.40**(-)	0.70***(+)	NS
NE	2006	7,170	11,029	10,364	$31,812	$48,517	$52,224	0.82***(+)	0.92***(+)	NS
NV	1996	7,629	10,018	8,893	$39,671	$48,869	$47,523	0.83***(+)	0.78***(+)	NS
NH	2004	6,981	10,476	9,652	$27,467	$47,285	$48,045	0.84***(+)	0.94***(+)	NS
NJ	2007	7,039	8,818	8,273	$32,742	$59,226	$55,908	0.80***(+)	0.93***(+)	0.93***(+)
NM	2007	8,679	13,638	12,283	$32,960	$40,982	$38,207	0.66***(-)	0.89***(+)	0.37**(+)
NY	2006	4,421	7,302	6,549	$36,653	$59,394	$60,078	0.98***(+)	0.89***(+)	NS
NC	2005	7,030	11,681	10,752	$27,286	$47,118	$45,166	0.97***(+)	0.93***(+)	0.39**(+)
ND	NA	8,095	NA	13,334	$31,973	NA	$58,474	0.57**(-)	0.82***(+)	0.86***(+)
OH	2004	6,668	9,739	9,704	$30,649	$44,473	$42,466	0.89***(+)	0.93***(+)	NS
OK	2006	9,060	13,622	12,543	$33,935	$41,260	$41,160	NS	0.85***(+)	NS
OR	1999	7,249	10,458	8,628	$31,103	$42,578	$48,809	0.82***(+)	0.60***(+)	0.59***(-)
PA	2004	6,053	8,724	7,784	$29,264	$44,381	$45,614	0.98***(+)	0.97***(+)	NS
RI	1999	5,727	8,358	7,521	$27,744	$42,303	$47,011	NS	0.52**(+)	NS
SC	2004	7,277	11,794	10,427	$24,141	$38,205	$36,056	0.95***(+)	0.98***(+)	0.91***(+)
SD	2006	8,968	11,627	10,930	$26,715	$45,711	$50,562	0.30*(+)	0.91***(+)	NS
TN	2004	7,298	11,990	11,055	$26,740	$42,976	$41,170	0.89***(+)	0.98***(+)	NS
TX	2000	8,024	10,554	9,263	$38,959	$45,798	$51,452	0.47**(-)	0.96***(+)	NS
UT	2002	7,423	10,522	9,317	$28,607	$39,958	$44,176	0.55**(+)	0.94***(+)	0.52***(-)
VT	2003	7,267	13,476	11,397	$25,918	$40,720	$42,375	0.97***(+)	0.65***(+)	NS
VA	1999	7,207	10,754	9,991	$29,954	$47,885	$53,555	0.97***(+)	0.63***(+)	NS
WA	1992	6,999	9,610	8,347	$34,804	$41,952	$52,277	0.81***(+)	NS	0.44**(-)
WV	2006	5,512	11,556	10,223	$25,774	$34,083	$35,631	0.34*(+)	0.87***(+)	NS
WI	2004	6,637	10,959	9,528	$30,687	$45,136	$44,356	0.92***(+)	0.97***(+)	NS
WY	2003	10,665	18,452	16,295	$60,625	$51,690	$67,217	NS	0.61***(-)	NS

NA= Not Applicable (for states that had not peaked as of 2011)

NS = Not Significant; *** Significant to 1% level; ** Significant at 5% level; * Significant at 10% level

Results: State-Level Decoupling of Driving from the Economy

The historic alteration of the relationship between the economy and driving that is being observed at the national level is also evident at the state level, especially when comparing the relationship on a decade-by-decade basis. In the 1980's, there was a strong (R>0.70) positive correlation between GDP per capita and VMT per capita for 33 states with another two states exhibiting moderate (0.30<R<0.70) positive correlations (significant to the 5% level; See Table 1). This relationship strengthened in the 1990's as 45 states had significant, positive relationships between the two variables (37 strongly- and eight moderately-correlated).

During the 1980's, 11 states had low (10%) or no significant relationship present and four states (Texas, North Dakota, Montana, New Mexico) had significant moderate, negative relationships where higher driving levels corresponded to lower levels of prosperity. In the 1990's, only Wyoming had a significant negative relationship between driving levels and GDP per capita.

By the 2000-2011 time period, the relationship between GDP per capita and VMT per capita at the state level experienced a radical change similar to the national patterns. At the state level, 30 states lacked any significant connection between the two variables for the 2000-2011 period and another two only had a relationship of low significance (10%); one negative (Alaska) and one positive (Alabama). Only nine states retained a strong, positive relationship and other five states a moderate, positive relationship. For this time period there were four states with a negative relationship (significant to 5% level); three moderately-correlated (Oregon, Utah and Washington) and Kentucky with a weak negative correlation.

Since the 1980's, VMT per capita growth rates have varied from state to state. The impact of VMT growth is evident when considering the economic-efficiency-per-mile-driven (GDP per VMT) over time. In 1980, Oregon, Utah, New Mexico and Mississippi had a GDP in the range of $3.53-$4.29 per mile driven (See Figure 2). Driving levels in New Mexico increased 57% from 8,679 in 1980 to its peak at 13,638 in 2007. During that same time period, the state's GDP decreased 80 cents per mile driven. From 1980 to its 2008 peak, Mississippi's economic efficiency decreased by $1.25 per mile while simultaneously increasing driving levels by over 125%. Following each state's peak and decline in VMT per capita, economic efficiency per mile has inched up slightly but, as of 2011, is still around a dollar lower than it was in 1980. Oregon and Utah, however, experienced driving and efficiency patterns that contrast that of New Mexico and Mississippi. While they experienced overall VMT per capita growth through most of the 1980's and 1990's, they peaked sooner and at lower levels than New Mexico and Mississippi. Oregon peaked in 1999 at 10,458 VMT per capita and 22 cents lower than its efficiency per mile than in 1980. The ensuing decrease in driving and increased economic growth has resulted in a GDP per VMT that is $1.59 higher than in 1999 and $1.37 higher than in 1980. Utah is similar, peaking in 2002 at around 10,500 VMT per capita and just five cents below its' 1980 GDP per VMT value. The recent economic growth without growth in driving levels has spurred a 95 cent increase in efficiency per mile from 2002 to 2011. When considered together, this four-state sample shows how states that began at a similar place in 1980 with respect to economic-efficiency-per-mile deviated over the 31-year span as a result of sharp differences in rate and duration of driving level growth. Earlier peaks at lower VMT per capita levels reflect higher efficiencies per mile driven.

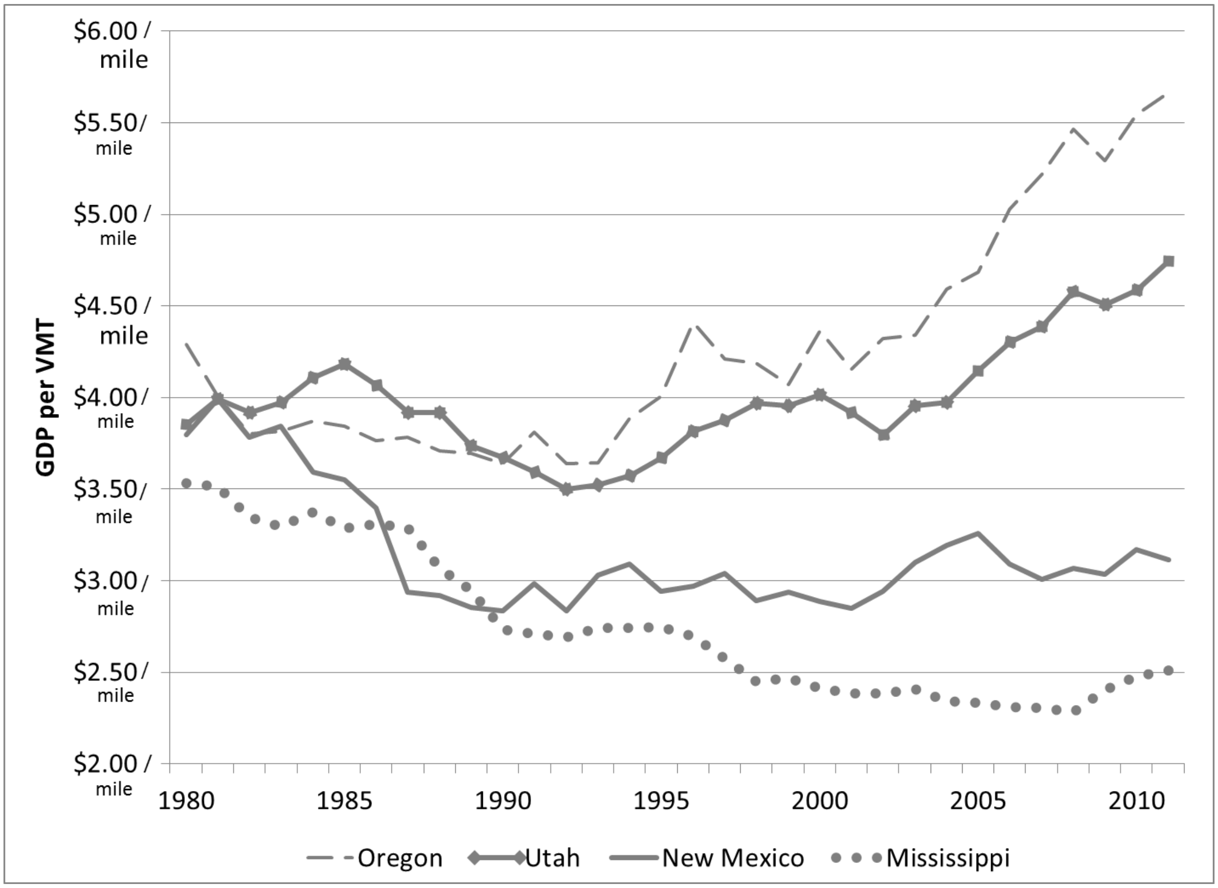

FIGURE 2: Changes in Gross Domestic Product per Vehicle-Miles Traveled (GDP per VMT) for a four-state sample, 1980-2011.

DISCUSSION

The patterns of peak car travel at the state level are notable for several reasons. First, since peak car travel has been observed in 96% of the states, this phenomenon is not limited to one specific "type" of state as could be described by such measures as degree of urbanity, demographic makeup, population density or by any other criterion of land use and the built environment. Peak car travel has occurred in high-driving states like Wyoming (16,272 VMT per capita in 2011) and Mississippi (13,044 VMT per capita in 2011) as well as in low per capita driving states like New York (6,562 VMT per capita in 2011) and Hawaii (7,322 VMT per capita in 2011). This reinforces the existing literature which has identified peak car travel as occurring across places that have more differences than similarities but yet are all seeing unexplained declines in driving levels. In addition to the geographically-transcendent nature of the phenomenon, it is important to highlight the timing of peak car travel, beginning as early as 12 years before the national peak and with eight states peaking before 2000. Despite compelling evidence that the rapid proliferation of Information Communication Technologies (ICT) have caused peak car travel (see Davis et al., *33*), many state-level peaks and declines commenced well before many technologies were introduced, let alone achieved significant market penetration.

As it relates to peak car travel's duration as a phenomenon, the state-level evidence suggests that this is very permanent in nature. The most recent peak occurred five years ago in 2009. Forty-seven other states peaked before that with over half peaking at least a decade ago, simultaneous with the national peak. One-in-five states had peaked as of 2000, nearly a decade-and-a-half ago. Though some states are experiencing small increases from one year to another, these may be more reflective of cyclical variations rather a return to record growth since they are still well below their record-high peak VMT per capita. Therefore, not only is peak car travel a long-standing phenomenon at the state level, it is also most likely a distinct new era of travel that Metz (*28*) identified. This new era of travel calls for research that revisits the extensive set of factors determined to impact travel behavior in the automobile growth era (*17*). Research opportunities include, but are not limited to: reexamining indicators of land use density and diversity, transit availability and quality, and state policies (e.g. gas tax). Doing so will determine how those factors may have evolved and contributed to the peak car travel phenomenon.

The relationship between GDP per capita and VMT per capita, once closely correlated, has decoupled in recent years at the national level and, as we have found with this research, at the state level as well. In some cases the relationship has turned negative but in most states the relationship has turned insignificant for the most recent time period considered. It is notable that the four states with significant negative relationships for 2000-2011 were four of the first states to experience peak car travel (Washington in 1992; Oregon and Kentucky in 1999 and Utah in 2002). If this is an indicator of a pattern, it is quite possible that states that peaked later may follow suit, resulting in new negative correlations between the two variables. This shift would stand in sharp contrast to decades of positively-correlated growth between economic output and driving levels. Regardless, the findings observed for 2000-2011 show that despite peak car travel, GDP has not peaked and that economic growth is occurring in a manner that is not necessarily related to driving levels. In this new era, decreases in VMT are not causing detrimental impacts to the economy. Rather, in many states, decreased VMT now associates with positive, not negative, economic growth. This stands in contrast to the apprehensiveness regarding VMT-reduction discussed earlier.

CONCLUSION

The new era of travel, referred to by others as "peak car," "peak travel" and by us in this paper as "peak car travel" began nationally in the U.S. in 2004 and has also been observed across the developed world. Potential explanations are varied and, while providing partial rationales, do not fully explain what appears to be a fundamental shift in travel behavior. Even ICT, which have dramatically altered patterns of daily life, have occurred too late to assume full responsibility for peak car travel, especially at the state level where 10 states peaked in 2000 or earlier, including Washington which peaked as early as 1992.

Though the cause of peak car travel is still not known, what is clear is that the relationship between driving levels and the economy, once strongly- and positively-correlated, has now undergone a revolutionary change such that, for most states, there is no longer any significant connection between GDP per capita and VMT per capita. Despite the peak and decline of driving levels, economic output has not peaked and is now growing. This shows that, despite the past complex relationship between the two variables and despite opposition to VMT-reduction policies that is grounded in concerns about economic output, economic output can increase without a need to simultaneously increase driving levels. It should also inform policymakers that transportation investments in this new era of travel should prioritize non-car modes since increased driving no longer associates with increased economic standing.

Our research has found that peak car travel is not a new phenomenon. It has been occurring for over a decade in the majority of states and for over 20 years in Washington State. The longevity of peak car travel at the state level is significant because it shows that the phenomenon has not been temporary by any means. As a result, instead of continuing a "wait-and-see" approach regarding peak car travel, it may be prudent to forge ahead on the basis that this represents a permanent structural change. To do so would require crafting more appropriate policies that are different from what have been pursued in the past. Considering that drivers pay only a portion of the true costs for highway travel in the U.S. with the remainder subsidized by the general taxpayer (*12,46*), government leaders should seriously reconsider traditional transportation planning approaches since continued prioritization of automobile travel appears to be an investment with diminishing returns. As was stated in a 2012 PIRG report (*47*, p.3), "It is time for policy-makers to consider the implication of changes in driving habits for the nation's transportation infrastructure decisions and funding practices, and consider a new vision for transportation policy that reflects the needs of 21st century America."

REFERENCES

1. Council of Economic Advisers. The cost of delaying action to stem climate change. Executive Office of the President of the U.S., 2014. http://www.whitehouse.gov/sites/default/files/docs/the_cost_of_delaying_action_to_stem_climate_change.pdf. Accessed July 31, 2014.
2. USDOT. *Transportation's role in reducing U.S. greenhouse gas emissions volume 1: Synthesis report*. Washington, D.C., 2010. http://ntl.bts.gov/lib/32000/32700/32779/DOT_Climate_Change_Report_-_April_2010_-_Volume_1_and_2.pdf. Accessed December 5, 2011.
3. Burbank, C.J. and P. Brinckerhoff. *Strategies for Reducing the Impacts of Surface Transportation on Global Climate Change: A Synthesis of Policy Research, State and Local Mitigation Strategies*. National Highway Cooperative Research Program Project, 20-24(59). AASHTO, 2009. http://climatechange.transportation.org/pdf/nchrp_2024_59_final_report_031309.pdf. Accessed March 5, 2012.
4. Garceau, T., C. Atkinson-Palombo, N. Garrick, J. Outlaw, J., C. McCahill, and H. Ahangari. Evaluating selected costs of automobile-oriented transportation systems from a sustainability perspective. *Research in Transportation Business & Management*, Vol.7, 2013, pp.43-53.
5. Moore, A.T., S.R. Staley, and R.W. Poole. The role of VMT reduction in meeting climate change policy goals. *Transportation Research Part A: Policy & Practice*, Vol.44,No.8, 2010, pp.565-574.
6. Pozdena, R.J. *Driving the Economy: Automotive Travel, Economic Growth and the Risks of Global Warming Regulations.* Cascade Policy Institute, 2009. http://cascadepolicy.org/pdf/VMT%20102109.pdf. Accessed Nov. 2, 2011.
7. Pisarski, A. The Nexus of Energy, Environment and the Economy: A Win, Win, Win Opportunity. *ITE Journal*, Vol. 79,No.1, 2009, pp.30-41.
8. Carlson, D. and Z. Howard. *Impacts of VMT Reduction Strategies on Selected Areas and Groups*. Washington State Department of Transportation, 2010. http://www.wsdot.wa.gov/research/reports/fullreports/751.1.pdf. Accessed November 1, 2011.
9. Poole, R. *Surface Transportaion Innovations #68.* Reason Foundation, 2009. http://reason.org/news/show/surface-transportation-innovat-68. Accessed November 2, 2011.

10. McMullen, B.S., and N. Eckstein. The relationship between vehicle miles traveled and economic activity. In *Transportation Research Record: Journal of the TRB, No.2297*, TRB of the National Academies, Washington, D.C., 2012, pp.21-28.
11. Ecola, L., and M. Wachs of the RAND Corporation. *Exploring the Relationship between Travel Demand and Economic Growth.* FHWA, 2012. http://www.fhwa.dot.gov/policy/otps/pubs/vmt_gdp/index.cfm . Accessed May 7, 2013.
12. Puentes, R. and A. Tomer. *The Road Less Traveled: An Analysis of Vehicle Miles Traveled Trends in the U.S.* Brookings Institute, Washington, D.C., 2008.
13. Liddle, B. Long-run relationship among transport demand, income, and gasoline price for the US. *Transportation Research Part D: Transport and Environment*, Vol.14,No.2, 2009, pp.73-82.
14. Newman, P., and J. Kenworthy. 'Peak Car Use': Understanding the Demise of Automobile Dependence. *World Transport, Policy & Practice,* Vol.17,No.2, 2011, pp.31-42.
15. Van Dender, K., and M. Clever. *New Recent Trends in Car Usage in Advanced Economies – Slower Growth Ahead? Discussion Paper No. 2013-09,* International Transport Forum, OECD, 2013. http://www.internationaltransportforum.org/jtrc/DiscussionPapers/jtrcpapers.html . Accessed May 15, 2013.
16. Goodwin, P., and K. Van Dender. 'Peak Car' – Themes and Issues. *Transport Reviews,* Vol.33,No.3, 2013, pp.243-254.
17. Garceau, T., C. Atkinson-Palombo, and N. Garrick. Peak Travel and the Decoupling of Vehicle Travel from the Economy: A Synthesis of the Literature. In *Transportation Research Record: Journal of the TRB, No. 2412*, TRB of the National Academies, Washington, D.C., 2014, pp.41-48.
18. Millard-Ball, A., and L. Schipper. Are we reaching peak travel? Trends in passenger transport in eight industrialized countries. *Transport Reviews*, Vol.31,No.3, 2011, pp.357-378.
19. Metz, D. Saturation of demand for daily travel. *Transport Reviews,* Vol.30,No.5, 2010, pp.659-674.
20. Litman, T. *The mobility-productivity paradox: Exploring the negative relationships between mobility and economic productivity.* Victoria Transport Institute, 2014. http://www.vtpi.org/ITED_paradox.pdf. Accessed July 9, 2014.
21. Kooshian, C., and S. Winkelman. *Growing Wealthier: Smart Growth, Climate Change, and Prosperity*. Center for Clean Air Policy. 2011. http://www.growingwealthier.info/index.aspx . Accessed Oct. 26, 2011.
22. U.S. Energy Information Administration. *Annual Energy Outlook 2013*. U.S Department of Energy, Washington, D.C, 2013. http://www.eia.gov/forecasts/aeo/. Accessed July 23, 2012.
23. Cohen, M.J. The future of automobile society: a socio-technical transitions perspective. *Technology Analysis & Strategic Management,* Vol.24,No.4, 2012, pp.377-390.
24. Schipper, L. Automobile use, fuel economy and CO2 emissions in industrialized countries: Encouraging trends through 2008? *Transport Policy*, Vol.18,No.2, 2011, pp.358–372.
25. Madre, J. L., Y.D. Bussière, R. Collet, and I.T. Villareal. *Are we heading towards reversal of the trend for ever-greater mobility?* Discussion Papers 2012-16, International Transport Forum, OECD Publishing, 2012. http://www.internationaltransportforum.org/jtrc/DiscussionPapers/DP201216.pdf. Accessed April 28, 2013.
26. Headicar, P. The changing spatial distribution of the population in England: Its nature and significance for 'peak car.' *Transport Reviews*, Vol.33,No.3, 2013, pp.310-324.
27. Lucas, K., & Jones, P. *The Car in British Society: Trends and Challenges*. The RAC Foundation, London, UK, 2009.
28. Metz, D. Peak car and beyond: The fourth era of travel. *Transport Reviews,* Vol.33,No.3, 2013, pp.255-270.

29. Kuhnimhof, T., R. Buehler, and J. Dargay. A New Generation Travel Trends for Young Germans and Britons. In *Transportation Research Record: Journal of the TRB, No.2230*, TRB of the National Academies, Washington, D.C., 2011, pp.58-67.
30. Litman, T. Changing travel demand: Implications for transport planning. *Institute of Transportation Engineers: ITE Journal*, Vol.76,No.9, 2006, pp.27-33.
31. Delbosc, A., and G. Currie. Causes of youth licensing decline: A synthesis of evidence. *Transport Reviews* , Vol.33,No.3, 2013, pp.271-290.
32. American Planning Association. *Investing in Place for Economic Growth and Competitiveness.* 2014. https://www.planning.org/newsreleases/2014/apr30.htm. Accessed June 30, 2014.
33. Davis, B. and T. Dutzik of The Frontier Group, and P. Baxandall of U.S. PIRG Education Fund. *A new way to go: The transportation apps and vehicle-sharing tools that are giving more Americans the Freedom to drive less.* 2013. http://www.uspirg.org/reports/usp/new-way-go. Accessed July, 2014.
34. Crocco, F., L. Eboli, and G. Mazzulla. Individual attitudes and shopping mode characteristics affecting the use of e-shopping and related travel. *Transport and Telecommunication,* Vol.14,No.1, 2013, pp.45-56.
35. Kuhnimhof, T., J. Armoogum, R. Buehler, J. Dargay, J.M. Denstadli, and T. Yamammoto. Men shape a downward ternd in car use among young adults – evidence from six industrialized countries. *Transport Reviews,* Vol.32,No.6, 2012, pp.761-779.
36. FHWA. *Annual vehicle-miles of travel, by state and functional system, 1980-1995, Table VM-2*. 2011. http://www.fhwa.dot.gov/policy/ohpi/hss/hsspubsarc.cfm. Accessed April 28, 2012.
37. FHWA. *Functional system travel, annual vehicle-miles, 1995-2011 Table VM-2*, 2014. http://www.fhwa.dot.gov/policyinformation/quickfinddata/qftravel.cfm. Accessed February 25, 2014.
38. U.S. Census Bureau. *Intercensal estimates of total resident population of states: 1980-1990. Table 2 Current Population Reports Series, P25-1106*, 1996. https://www.census.gov/popest/data/state/asrh/1980s/tables/st8090ts.txt. Accessed April 28, 2012.
39. U.S. Census Bureau. *State population estimates: Annual time-series, 1990-1999. ST-99-3.* 1999. https://www.census.gov/popest/data/state/totals/1990s/tables/ST-99-03.txt. Accessed April 28, 2012.
40. U.S. Census Bureau. *Annual estimates of population for U.S., Regions, States and Puerto Rico, 2000-2009. Table 1*. 2009. https://www.census.gov/popest/data/intercensal/state/state2010.html. Accessed April 28, 2012.
41. U.S. Census Bureau. *Annual estimates of population for U.S., Regions, States and Puerto Rico, 2010-2011. Table 1*. 2011. https://www.census.gov/popest/data/historical/2010s/vintage_2011/state.html. Accessed April 28, 2012.
42. U.S. Bureau of Economic Analysis. *Gross Domestic Product by State, All industry total, SIC, 1963-1997*. 2013. http://www.bea.gov/iTable/iTable.cfm?reqid=70&step=1&isuri=1&acrdn=1#reqid=70&step=1&isuri=1. Accessed May 7, 2014.
43. U.S. Bureau of Economic Analysis. *Gross Domestic Product by State, All industry total, NAICS, 1997-2012*. 2013. http://www.bea.gov/iTable/iTable.cfm?reqid=70&step=1&isuri=1&acrdn=1#reqid=70&step=1&isuri=1. Accessed March 26, 2014.
44. Coin News Media Group LLC. *US Inflation Calculator: Consumer Price Index data from 1913 to 2014: All Urban Consumers (CPI-U).* 2014. http://www.usinflationcalculator.com/inflation/consumer-price-index-and-annual-percent-changes-from-1913-to-2008/. Accessed June 2, 2014.

45. Esri. *USA_states.lpk*. 2013. http://www.arcgis.com/home/item.html?id=1a6cae723af14f9cae228b133aebc620. Accessed July 24, 2014.
46. Zhu. P. and J.R. Brown. Donor states and donee states: investigating geographic redistribution of the US federal-aid highway program 1974–2008. *Transportation*, Vol. 40,No.1, 2013, pp.203-227.
47. Davis, B. and T. Dutzik of The Frontier Group, and P. Baxandall of U.S. PIRG Education Fund. Transportation and the New Generation: Why young people are driving less and what it means for transportation policy. 2012. http://www.frontiergroup.org/reports/fg/transportation-and-new-generation. Accessed April, 2014.

CHAPTER 4: Decreasing Vehicle Miles Traveled (VMT) per capita in the United States: The Role of the Back-to-City Movement, Smart Growth Policy, Demographic Changes and Increased Poverty

ABSTRACT

While peak car travel began at the state-level in the United States (U.S.) as early as 1992, the nature of this phenomenon is still not fully understood. Travel behavior research is well-established and extensive in identifying that travel behavior is impacted by locational factors including the built environment and characteristics of the transportation systems as well as by socioeconomic traits and access to various technologies. In the U.S., the state is the political unit at which many policy and funding decisions that affect transportation and land use are made and ultimately affect the travel behavior of residents. With respect to this new era of decreased driving levels, few studies have taken an approach that considers socioeconomic and built environment factors while also acknowledging the role that states can have in affecting VMT per capita. This paper incorporates state-level data for 1990, 2000 and 2010 into a fixed-effects panel model to determine the relative impact of various factors affecting travel behavior. Using this approach, driving reductions at the state-level appear to result from a complex combination of factors that are affecting changes in different states in different manners. Some changes appear to be the deliberate result of growth management policies while other driving reductions are related to demographic and economic changes. Although socioeconomic factors appear to have a short- and mid-term effect in reduced driving, it is clear that state governments can use policy and funding decisions to structurally change travel behavior.

INTRODUCTION

In the 20th century, the amount of driving in the United States (U.S.), as measured by vehicles miles traveled (VMT) per capita grew to record levels on a near annual basis (*1-2*). Other than World War II and the energy crises of the 1970's and 1980's, VMT per capita continued its overall growth pattern until 2004, when it peaked at over 10,000 miles per capita and then began a nine year national decline (*2-3*). At the statewide scale, this new era of travel (*2,4*) began as much as twelve years before the national peak, with Washington State reaching its record high in 1992 and then posting strong declines since that time (*2*). Driving levels in Washington, above the national average prior to peaking, have decreased below the national average since peaking. It appears these reductions could be related to multiple policies and programs within Washington aimed at relieving traffic congestion, preventing low-density sprawl and reducing carbon emissions (*5*). Washington, D.C. and Nevada were the next to peak in 1996 and six more states peaked by the close of the 20th century (*2*). By 2011, peak and ensuing declines had commenced in all states except for Alabama and North Dakota (*2*).

Despite being a widespread and longstanding phenomenon (*2*), the causes of peak car travel are still not fully understood (*1,6-7*). Several explanations of peak car travel have been suggested such as: declines in driving among younger Americans (the "Millennial generation") (*8-10*); population aging, particularly among retiring "Baby Boomers" (*10-11*); preference shifts from suburban to urban living among the Millennials and Baby Boomers resulting in what has been identified as the "Back-to-City Movement" (*10-12*). Information Communication Technologies (ICT) (such as internet access, online shopping, and smart phone technology) have been recognized as impacting travel behavior (*13*). Despite evidence of significant usage increases in ICT from 2000 to 2012, ICT's effect on travel behavior is still unclear and putting too much emphasis on ICT may undervalue the influence of other social factors (*14-16*). Furthermore, considering this new era of travel began in the 1990's for several states and that the U.S. peaked prior to the recent proliferation of ICT, the suggestion that ICT is the primary contributor to driving reductions may be misguided (*2,17*).

In seeking to explain causal factors of peak car travel, several researchers have utilized National Household Travel Survey (NHTS) data to assess behavior changes at the individual scale (*15-16,18*). Their focus is generally on the changing travel patterns of Millennials who were found to be driving less than their predecessors. Blumenberg et al (*16*) conclude that these changes are mainly due to economic limitations since Millennials were the hardest hit by the Great Recession. These studies provide critical insight into factors affecting individual travel behavior in the U.S. that may be contributing to decreased driving rates. An individual scale approach to modeling, however, also has its limitations. Using NHTS data at the individual scale does not account for geographic variations related to differences in economic conditions, urban development patterns and the availability of transportation options. Specifically, an individual scale approach does not acknowledge the fact that in the U.S., individual states have jurisdiction over land use and transportation policy as well as allocating federal and state funding for transportation improvements. While most states are now decreasing in VMT per capita, record peak values ranged from 7,302 in New York to 18,452 in Wyoming (*2*), an indication that individual travel behavior is strongly impacted by state-level geographic and political factors. This research study is conducted at a statewide scale approach to specifically examine geographic variations in what factors are shaping this new era of travel.

BACKGROUND / LITERATURE REVIEW

To identify the factors contributing to decreased VMT per capita, it is important to acknowledge the complex array of factors known to affect travel behavior in the first place (*1*). The travel behavior literature is well-established and has found that the influences on individual mode choice and distance traveled can be broadly grouped into two categories (*1*): 1) built environment factors (*19-26*); and 2) socioeconomic factors (*21,24*).

Factors Affecting Travel Behavior

Built environment factors found to affect travel behavior include: density and proximity of population and employment (*19*,*25*,*27*-*28*); urban layout, form and location of residential neighborhoods (*29*-*30*); land-use mixing (*21*,*26*,*31*); and the provision of transportation facilities (*21*,*32*-*33*). Since higher residential densities reduce car ownership which in turn reduces driving rates (*31*-*32*), population density is considered to be one of the most effective urban variables in determining travel behavior (*28*,*34*). As could be expected, transit availability also has an impact on driving levels but often not without consideration of the impacts of the previously-discussed factors (*15*,*21*,*32*).

While built surroundings have a strong bearing on travel, household socioeconomic characteristics can also strongly affect travel behavior (*21*,*24*). Life-cycle factors, such as age, employment status and presence of children are key travel behavior determinants (*15*,*35*-*36*). Household income can impact the ability to own and operate automobiles (*38*). Once a household can afford the initial investment in car travel, however, they are more likely to make trips by car (*38*-*39*). As indicated earlier, determinants of travel behavior are strongly interconnected. For example, a household's socioeconomic characteristics can impact household location which is then impacted by the surrounding built environment (*35*,*37*). Residential sorting is strongly tied to income and ultimately affects what type of destinations and transportation modes a household can access (*35*,*37*). Wealthier communities may be able to provide better quality non-car infrastructure that makes walking, biking and transit ridership more desirable (*40*).

In addition to the built environment and socioeconomic factors, many decisions are made at the state level that affect development patterns and the character a transportation system that ultimately affect the travel behavior of those living within the state. Washington, the first state to enter the peak car travel era in 1992 (*2*), established a Growth Management Act (Revised Code of Washington Chapter 36.70A) in 1990 that mandated municipalities develop comprehensive plans and delineate urban growth areas to limit low-density sprawl (*41*). In addition, Washington also instituted a Commute Trip Reduction program in 1991 that worked with employers to shape employee travel behaviors in a manner that reduced single-occupancy vehicle commutes and promoted travel by carpool, transit and non-motorized means (*42*). Oregon, which peaked in 1999, is well-known for its Land Conservation and Development Act which it adopted in 1973 in protect farmlands and forests from suburban development (*41,43*). Like Washington, Oregon's act mandated comprehensive planning and urban growth area delineation.

In recent times, 33 states have developed climate action plans to reduce greenhouse gas (GHG) emissions (*5*). Many of these states have incorporated a host of strategies for reducing VMT as a means towards reducing emissions (*5*). In 2008, California adopted the Sustainable Communities and Climate Protection Act which seeks to reduce automobile use and associated emissions through coordinated land use and transportation planning (*44*). Texas was the first state to allow pay-as-you-drive car insurance to incentivize reduced driving (*5*). The Brookings Institute (*45*) estimated that if pay-as-you-drive were available and utilized nationwide, that U.S. driving levels would decline eight percent. These programs are just a sampling of state-level policies that can impact VMT per capita.

Seeking the Cause of Peak Car Travel

To date, there has only been a limited amount of research focused on the factors related to decreasing VMT per capita in the new era of travel (*2,4*). Of the existing studies, there is a strong focus on the evolving travel patterns of Millennials (*15-16,18*). Using National Household Travel Survey (NHTS) data for 2009, Teeparthi (*15*) finds that Millennials drive less than the other cohorts. However this study is cross-sectional in nature and does not do a temporal comparison to other generations while at the same age. To provide insight into generational changes, Davis et al., for U.S. PIRG, (*18*), compared 2001 to 2009 NHTS data and determined that 16-34 year olds in 2009 drove approximately 2,400 miles less than the same age group did in 2001, most likely as a result of gas prices, stricter licensing laws and changes in technology and preferences among Millennials. Also with a focus on changing travel behavior among Millennials, Blumenberg et al. (*16*) compared National Personal Transportation Survey data from 1990 to NHTS data from 2001 and 2009. Their analysis confirms that younger generations are driving less but they determine this change is due to economic factors rather than preference-based as Millennials have been most impacted by lower wages and unemployment (*16*). They conclude that, aside from economic constraints, youth travel behavior is actually more similar to that of prior generations despite the dramatic changes in technology, policy and societal norms since 1990 (*16*).

When studying individual travel behavior, data at the individual scale (such as is the NHTS data utilized in the prior three studies) provides important insight into factors affecting individual decisions and behaviors. This approach is limited, however, as it does not account for differences in political geography that can significantly impact travel behavior such as variations from state to state in terms of policies, political structures and funding mechanisms that can dramatically affect land use development patterns and the provision of transportation (*2*). In addition, while younger generations have been found to drive less (*15-16,18*), focusing only on Millennial travel patterns ignores the fact that VMT per capita decreases are happening in a widespread geographic manner that regardless of a population's age-structure (*2,46*). In addition, the individual scale focus does not consider that there may be strong geographic variations in the causes and character of peak and declining driving levels. Considering that states peaked at anywhere from 7,302 to 18,452 VMT per capita, it appears that there are geographic factors that serve to induce or reduce driving within a state. To provide a more thorough understanding of this new era of travel in the U.S., research is needed that considers that driving decreases, though widespread, may be occurring in a manner with strong geographic variation related to the geographic and political contexts at the state level.

RESEARCH METHODS

While the series of factors impacting travel behavior occur at different geographic scales, the state level of analysis is a critical scale to assess peak car travel since the state is the political scale at which many decisions that directly or indirectly affect transportation are made. The study area includes all 50 states and Washington, D.C. (n=51). In performing an analysis at the statewide scale, however, it is acknowledged that many of the travel behavior determinants are not relevant for inclusion and are therefore omitted from this study. Transportation factors such as the presence of bicycle infrastructure and transit system characteristics would be best analyzed at the neighborhood, municipal or metropolitan scale. Similarly, local policies such as zoning ordinances and parking and congestion pricing most likely affect travel behavior as well but may be of limited value when considered at the statewide scale. The independent variables included in this analysis are meant to represent some of the variations that occur from one state to another, often as a result of a state's political, demographic and economic makeup.

Data

Population density is one of the most effective urban indicators of travel behavior (*19,28,34*). When considered at the state-level, however, a state's overall population density can be diluted by a state's geographic size and therefore not provide an adequate indication of density patterns within a state (*47*). In order to incorporate density data that is more representative of population distribution patterns, population-weighted densities were calculated using census tract data. Until the 1990 census, when all of the U.S. was divided into census tracts for the first time, most of the geographic area of the U.S. was not included into census tracts (See map at: http://www.s4.brown.edu/us2010/Researcher/Bridging.htm). Since 1990, other than regular census tract changes related to population changes and improvements to data-gathering techniques, the tract-level data is relatively consistent. Therefore, 1990 was selected as the earliest year of inclusion in data modeling.

In all of our analyses, VMT per capita is the dependent variable. The dependent variables included were selected to serve as proxies for the broad categories of factors found to affect travel behavior: built environment, transportation system characteristics, economic and demographic characteristics (see Figure 1). As represented in Figure 1, we acknowledge that technology and policies also have an impact on travel behavior. With respect to technology, we have opted to omit variables for several reasons. First, revolutionary advancements have taken place in the 2000's that would therefore not be represented in 1990 data, the starting year of our analysis. In addition, one can reasonably assume that access to technology across the U.S. is relatively even and that any uneven access may be more tied to economic constraints (for which we have proxies). As a result, any impacts from technology would be related to an unobserved time effect in the model. For the policy category, there are no variables included that directly represent this effect. However the transportation and built environment variables could potentially reflect the outcomes of policies that were enacted (for example urban growth boundaries could increase densities and providing transit could alter mode share). As such, we feel that the policy category is indirectly represented by variables in the other categories and those that are not captured will relate to an unobserved state effect in the panel model.

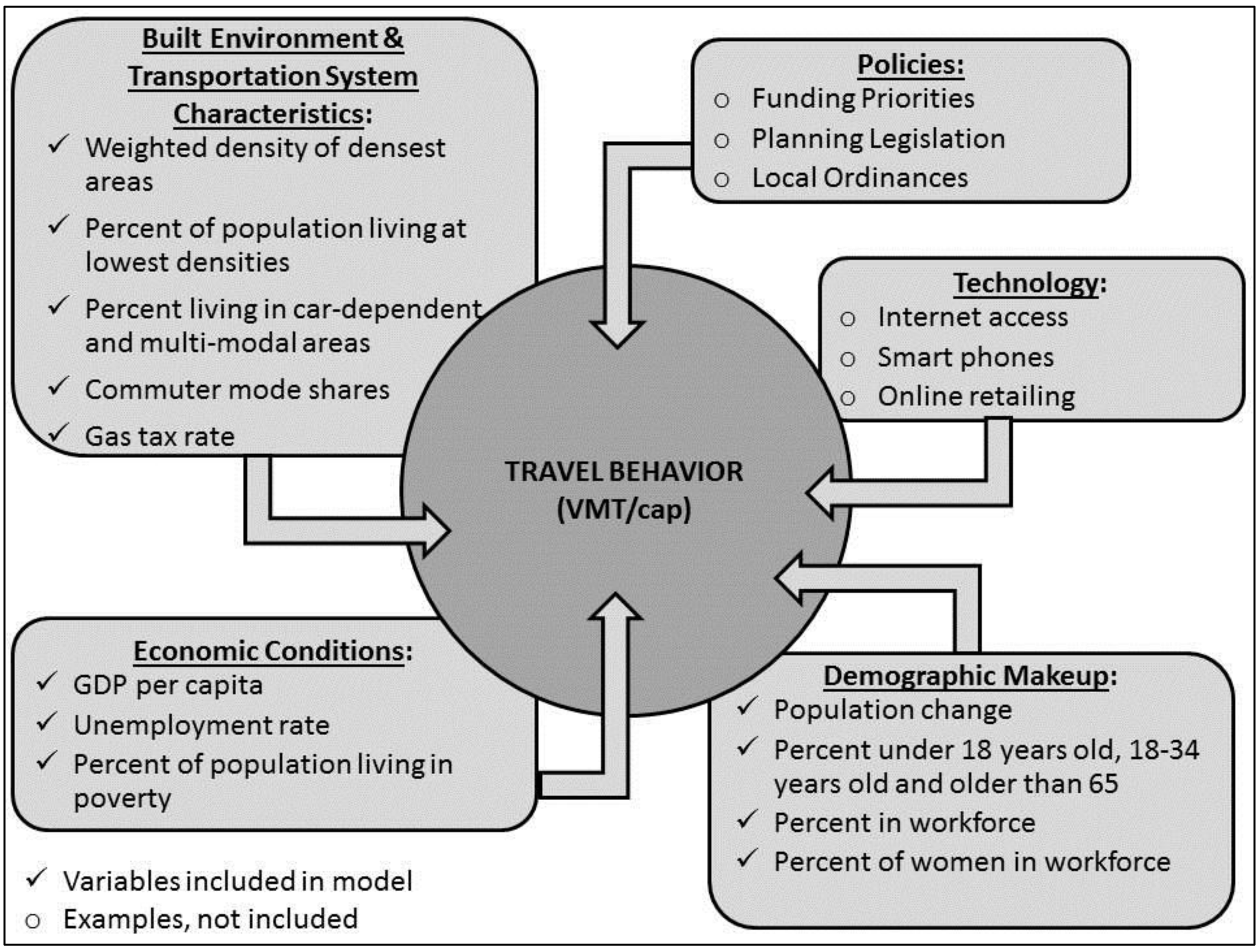

FIGURE 1 Conceptual Model of Travel Behavior (Created by author).

Variables Included

Numerous independent variables were considered in order to represent the characteristics of a state's built environment, transportation system and socioeconomic makeup. Built environment and transportation system indicators included: the weighted population densities of a state's densest areas; the percent of people living at extremely low densities; commuter mode shares in urban centers; state gas tax (cents per gallon, adjusted to 2011$; *48*-*49*); and the percent of people living in multimodal areas. The economic indicators included were: Gross Domestic Product (GDP) per capita (adjusted to 2011$); unemployment rate (as a percent of available workforce; *50*); and poverty levels (percent of a state's population living at or below the poverty line; *51*). Demographic variables included were: overall population rate of change (*52*-*54*); the percent of the population in three distinct age cohorts (under 18, 18-34 and older than 65; *55*); the percent of the population in the workforce and the percent of women in the workforce (*50*).

Preparation of Raw Data

To calculate per capita values, overall state data (VMT, *56*-*57*, and GDP, *58*-*59*) were divided by a state's population (*52*-*54*). We used census tract-level data for density (*60*) and for commuter mode share (*61*) in order to gain a more accurate representation of distributions and behaviors than is possible using data aggregated to state level. The decennial census for 1990 and 2000 include mode share data but the 2010 census does not. As the U.S. Census Bureau shifted this type of data gathering for 2010 to the American Community Survey (ACS), 2008-2012 ACS census tract data was utilized as a stand-in for 2010 values. Census tracts for any data year that lacked commuter mode share data were removed from the analysis. Typically omitted census tracts were those with minimal or no residential populations (e.g. tracts dominated by commercial, industrial or open space uses) or those dominated by correctional facilities.

The census tract data was then utilized for calculating numerous variables. To generate each state's indicators of built environment and urbanity, census tracts for each state and time period were ranked in order by their density and then grouped into the 0-10th percentile (by population) and 10-30th percentile in order to represent the densest areas of each state. Population-weighted densities were then calculated for each of these groups. To represent the lowest densities, the percent of a state's population living below 300 people per square mile were also calculated. Weighted commuter mode shares of the densest 0-10th and 10-30th percentiles were calculated as indicators of transportation system characteristics. Census tract data was also ranked in order by car share to calculate the percentage of people living in tracts with greater than 85% car commuting shares ("car-dependent" areas) and the percentage of people living in tracts with less than 85% car shares where greater than 15% commute by non-car shares to represent areas offering comparative multimodal travel opportunities.

Methods

This research utilizes a fixed-effects panel model in order to understand the role of the various independent variables in generating VMT per capita and also to attempt to capture where less easily-observable factors have an effect as well. Panel models can pick up the effect of omitted variables in three ways: 1) state invariant – time varying variables (such as changes in technology that evolve over time but are relatively constant across the states; 2) state varying- time invariant variables that vary from state to state but are relatively constant within a state over a particular time (such as cultural/political contexts of state); and 3) state varying – time varying which represent factors that vary from state to state and over time (such as changes in regulations, policy and funding priorities). The benefit of using this model as it relates to peak car travel is to identify geographic variations to see how traditional and evolving approaches to planning, transportation, economic development and other factors affected by state-level policy and decision-making vary from state to state.

The data panel includes 153 observations (51 states in three time periods: 1990, 2000 and 2010). We ran multiple panel models to assess the effects of all variables. The first model included all independent variables outlined above and ensuing models included various combinations of these independent variables with a goal of selecting a final model that included the widest array of statistically-significant variables. As correlation between independent variables may lead to problems with multicollinearity, we quantified the cross-correlation between variables, and removed variables with covariance over 0.70. After removing insignificant variables and those with high multicollinearity, we identified the strongest combination of variables for our final model. To check for robustness, we ran a series of panel models using the selected variables in different manners: a panel model with the actual value of each variable; a panel model with the natural-log of each variable; and a panel model with the average annual rate of change over each decade for the selected variables. The patterns were consistent among the different models and builds confidence in the variable selections and modeling approach. As the natural-log transformed normal regression model was the strongest overall, this is the model for which results are presented and discussed in this article. The model is specified as follows:

$$\log(VMTcap_{st}) = \beta\log(BT_{st}) + \alpha\log(Ec_{st}) + \gamma\log(De_{st}) + (SX = F) + \sum \theta_t + \varepsilon_{st}$$

Where:

$VMTcap_{st}$ refers to VMT per capita of state "s" at time "t";
BT_{st} refers to a set of built environment and transportation variables;
Ec_{st} refers to a set of economic variables;
De_{st} refers to a set of demographic variables;
β, α, and γ refer to coefficients of BT, Ec and De;
(SX=F) represents the fixed effect for each state;
θ_t represents the time dummy variables;
and ε_{st} is the error term.

Variables included in the natural-log transformed regression model were:

- *Built environment and Transportation*: 1) population-weighted density for the densest 10% of each state; 2) percent of the population living at extremely low densities (<300 people per square mile; 3) percent of the population living in multimodal places; and 4) state gas tax rate.
- *Economic*: 5) percent of population living in poverty;
- *Demographic*: 6) percent of population under 18 years old; and 7) percent of population over 65 years old.

RESULTS

Three of the four built environment and transportation indicators were negatively-correlated with VMT per capita (See Table 1). Higher densities in urban areas, higher shares of population living in multimodal areas and higher state gas tax rates (cents per gallon) are all associated with lower driving levels. The final variable for this group, percent of the population living in low density areas, is positively related to VMT per capita. When considered together, these four variables indicate that increasing urban densities while decreasing low density living can result in VMT per capita reductions. Since the state level is where many land use and transportation policies are initiated, enabled or mandated, this seems to show that states with Smart Growth policies that have promoted densification while inhibiting low-density sprawl are contributing to VMT per capita reductions within their jurisdictions. The provision of opportunities for multimodal travel, though not as strong an effect in reducing VMT per capita as increasing densities or higher gas tax rates, still shows that providing more opportunities for non-car commuting will serve to lower trips by car and miles-driven as a result. The gas tax rate most likely has a dual-fold relationship with VMT per capita. First, higher gas tax rates would also mean that with gas prices held steady, that it would cost more to drive in states with higher gas taxes than those with lower gas taxes, thus lowering driving rates in higher tax states. In addition, changes to the gas tax rate are often subject to strong political debate therefore higher gas tax rates help to represent states that are moving away from heavily subsidizing car travel and moving towards user-based costs.

The percent of people living in poverty, as might be expected, also has a negative effect on driving. Where more of the population is living in poverty, the ability to afford to purchase or operate a car is restricted for more of the population and would result in decreased driving. In addition, since living below the poverty rate is strongly-correlated with unemployment, a lack of employment removes a necessary commute that would, if taken by car, generate higher VMT per capita.

In terms of demographic shifts, model results indicate that both higher shares of under-18 population and over-65 population have a negative effect on driving. The under-18 finding makes sense since most of the population under the age of 18 is not legally old enough to drive therefore increasing this population within a state would increase the “per capita” but not increase the number of miles-driven, thus serving to reduce VMT per capita. Similarly, the over-65 population consists of those close to retirement, semi-retired or retired. For those semi-retired or in retirement, commute-based mileage accumulation is either reduced or negated; reducing VMT per capita.

TABLE 1: Results of Fixed-Effects Panel Model

Category	Variable (Log of each)	Coefficient	Std. Error	t-Statistic	Prob.
	Constant	9.285	0.226	41.153	0.000
Built Environment & Transportation	Density of the densest areas	-0.176	0.017	-10.519	0.000
	Population living in low density areas	0.022	0.002	9.369	0.000
	Population living in multimodal areas	-0.021	0.009	-2.276	0.025
	Gas tax rate	-0.032	0.018	-1.778	0.079
Economic	Population living in poverty	-0.094	0.024	-3.865	0.000
Demographic	Under-18 population	-0.333	0.075	-4.450	0.000
	Over-65 population	-0.348	0.043	-8.084	0.000
Time-Effects	1990 to 2000	0.107	0.003	31.036	0.000
	2000 to 2010	0.109	0.010	10.539	0.000
State-Effects	Alabama	0.08	Montana		0.06
	Alaska	-0.66	Nebraska		0.03
	Arizona	0.05	Nevada		-0.11
	Arkansas	-0.07	New Hampshire		-0.17
	California	0.09	New Jersey		0.04
	Colorado	-0.12	New Mexico		0.18
	Connecticut	-0.03	New York		0.10
	Delaware	0.09	North Carolina		-0.10
	District Of Columbia	-0.06	North Dakota		0.08
	Florida	0.10	Ohio		-0.03
	Georgia	0.01	Oklahoma		0.12
	Hawaii	-0.04	Oregon		-0.01
	Idaho	-0.02	Pennsylvania		0.01
	Illinois	0.03	Rhode Island		-0.09
	Indiana	0.04	South Carolina		-0.09
	Iowa	-0.04	South Dakota		0.06
	Kansas	-0.04	Tennessee		-0.02
	Kentucky	0.03	Texas		-0.02
	Louisiana	0.01	Utah		-0.06
	Maine	0.02	Vermont		0.02
	Maryland	0.02	Virginia		0.01
	Massachusetts	0.03	Washington		-0.07
	Michigan	-0.02	West Virginia		-0.07
	Minnesota	0.04	Wisconsin		0.10
	Mississippi	0.04	Wyoming		0.32
	Missouri	0.14			

DISCUSSION

The fixed-effect panel model results provide insight of two main time-based patterns of VMT per capita decreases. For states that peaked earlier, the peaks appear related to changes in the built environment and transportation system that any other categories. For states that peaked later on, the decline in VMT per capita appears more related to widespread demographic changes and economic conditions that also served to reduce driving levels further in some states that had peaked prior to 2004.

First, for the earliest states to peak and decline, decreased driving appears to be more related to density patterns indicative of stronger anti-sprawl policies as well as the Back-to-City migration (*10-11*) resulting from a preference for urban living among Millennials and Baby Boomers alike (*12*). Of the nine states peaking in the 1990's, seven of them increased their densities of urban centers during the 1990's while all nine decreased their shares of the population living at low densities during the same time period. In considering all 16 states to have peaked prior to the national peak in 2004, 11 of the 16 early peaking states increased densities in their urban cores and 14 of 16 posted decreases of the low density population share in both decades of the analysis. In addition to the role that increasing densities serves in decreasing VMT per capita, there also appears to be a transit demand that develops as places densify. In considering all the states that increased their urban core densities during the 1990's (regardless of peak year), all 24 of these states increased the share of their populations living in multimodal areas during the 2000's. It seems that the preference shift towards urban neighborhoods has ultimately led to the increase in transit opportunities and non-car travel.

With respect to demographic changes, aging of the U.S. population as represented by growth of the over-65 age cohort contributed to driving decreases in 46 states during the 2000's. For the 15 states that peaked prior to 2004, aging contributed to additional VMT per capita decreases. For the 22 states that peaked after the national peak (from 2005-2009), 20 states had decreases related to an aging population. Similarly, increased poverty in 47 states limited driving and served to reduce driving in the 2000's. Of the 22 states peaking after 2004, 20 experienced higher rates of poverty during by 2010 that resulted in lower driving. While the increased densities of urban areas contributed to increased transit opportunities as discussed above, there is also an economic pattern that develops in the 2000's as it relates to non-car travel. As 47 of 49 post-peak states saw decreases related to increased poverty, 46 of the 49 states experienced growth in the percent of people living in areas with non-car commuting over 15%. Similarly, of the 22 latter peaking states, decreases occurred in 20 states as a result of growth in non-car commuting just as 20 states in this group experienced increased poverty. Though it may not necessarily be the case for all the states, it does appear that the modal shift is at least partly the result of economic necessity.

Regarding the two states that had were still recording record VMT per capita growth, Alabama is starting to see a slight increase in people living in multimodal areas in the 2000's and, like most of the U.S., is aging. Countering those changes are continued density decreases and a weakening gas tax (when correcting for inflation) that not only is associated with higher rates of travel but also indicates that Alabama has not taken any significant state-level action to deliberately contain sprawl or reduce VMT per capita. North Dakota, the other state to have not peaked, exhibits similar patterns of decreasing densities and gas tax rate performance. Due to the influx of oil workers into the state in the 2000's, working-age population increased and decreased the share of over-65 residents.

CONCLUSION

Despite peak car travel's longevity at the state level, the causes of this phenomenon were still unclear. In utilizing a fixed-effects panel model approach for the 1990's, 2000's and 2010's, the role of various travel behavior actors were assessed to see how they impact driving level changes during the subject time period. Overall, the causes of VMT per capita decreases are complex, multi-faceted and vary from state to state. Different factors are affecting changes in travel in different states in different ways. With respect to the group of state that peaked over 15 year ago, the ensuing declines in driving appear to be more related to the Back-to-City movement and state level policies aimed at curbing low density sprawl and promoting coordinated transportation and land use planning. Consistent with Metz (*4*) and Garceau et al. (*2*), this appears to be a "New Era of Travel," at least in states that have made deliberate choices to break the predict-and-provide approach to transportation planning and focus on provide access through diverse land use patterns that support multimodal travel. For the states that peaked in the mid to late 2000's, however, it is not as clear whether they are entering this new era as their driving decreases are more of an unintended byproduct of demographic shifts and economic conditions.

The finding that economic factors appear to have a significant role in decreasing VMT per capita is consistent with Blumenberg et al. (*16*). While echoing Blumenberg at al.(*16*), our research also advances their study in multiple ways. First, in using state-level approach, we find that states with a larger proportion of residents over 65 years old have strong decreases in driving and that, as the entire nation increases the share of the over-65 cohort, driving decreases will most likely continue to occur. Second, using the fixed-effects panel model at the state-level also provides valuable insight into the role that states play in travel behavior. While the individual scale of analysis (such as: Teeparthi, *15*; Blumenberg et al., *16*; and Davis et al., *18*) is essential in analyzing individual travel behavior, these methods do not account for variations at broader geographic scales that can also serve to affect individual travel behavior. Municipalities, metropolitan planning organizations, counties and states are all political units that make policy and budgetary decisions that affect transportation options and travel behaviors of their constituents. Analyzing the factors affecting travel behavior at each of these geographic and political scales is imperative to understand the extent to which different scales of government can impact travel behavior. This paper fills a gap in state-level research and finds that there is in fact a strong variation from state to state in impacting VMT per capita. Some state-level variations are the results of deliberate efforts to reducing driving while other policies, or in some cases a failure to adopt certain policies, can inadvertently affect travel patterns as well. While peak car travel is a widespread phenomenon, its occurrence at the state level is the result of a complex combination of state-level policymaking, economic changes, demographic shifts and commuter patterns.

Although increased poverty is contributing to declines in driving, this does not mean the improvements in this indicator will lead to a return to record growth in VMT per capita. Demographic changes, specifically the aging of the population, will not likely change course in the near future and, in combination with deliberate state-level VMT-reduction strategies, will continue to contribute to decreased driving in the future. States that were found to have a positive effect on inducing car travel should consider demographic changes and the economic standing of their residents and realize that an automobile-focused transportation system may not serve the needs of its people, whether now or into the future. These states should reconsider their highway-oriented approaches in favor of policies and planning that provide transportation options. In settings with more diverse land use and transportation options, travelers can choose to switch modes whether they do so by preference or out of necessity due to changing economic conditions. Complementary and diverse transportation and land use systems will provide the ability for residents to make individual decisions regarding travel based on their own situation rather than, when living in automobile-dependent areas, being forced to choose between costly car trips or eliminating trips altogether. By taking a more comprehensive approach, states can reduce dependence on the automobile and, in turn, reduce some of the negative consequences of widespread automobile dependence.

REFERENCES

1. Garceau, T., C. Atkinson-Palombo, and N. Garrick. Peak Travel and the Decoupling of Vehicle Travel from the Economy: A Synthesis of the Literature. In *Transportation Research Record (TRR): Journal of the Transportation Research Board (TRB), No. 2412,* TRB of the National Academies, Washington, D.C., 2014, pp.41-48.
2. Garceau, T., C. Atkinson-Palombo, and N. Garrick. Peak Car Travel in the United States: A Two-Decade Long Phenomenon at the State Level. In *TRR: Journal of the TRB, No. 2531*, Washington, D.C., 2015.
3. McCahill, C. *Per-Capita VMT drops for ninth straight year; DOTs taking notice*. State Smart Transportation Initiative., 2015. http://www.ssti.us/2014/02/vmt-drops-ninth-year-dots-taking-notice. Accessed July 27, 2015.
4. Metz, D. Peak car and beyond: The fourth era of travel. *Transport Reviews*, Vol.33,No.3, 2013, pp.255-270.
5. Texas Transportation Institute. *Methodology for estimating greenhouse gas emissions and assessing mitigation options for project level application for on-road mobile sources, Volume 2 – White Paper on New Directions in Greenhouse Gas Emissions and Climate Change*. 2011. tti.tamu.edu. Accessed July 2015.
6. Cohen, M.J. The future of automobile society: a socio-technical transitions perspective. *Technology Analysis & Strategic Management,* Vol.24,No.4, 2012, pp.377-390.
7. Schipper, L. Automobile use, fuel economy and CO2 emissions in industrialized countries: Encouraging trends through 2008? *Transport Policy*, Vol.18, No.2, 2011, pp.358–372.

8. Delbosc, A., and G. Currie. Causes of youth licensing decline: A synthesis of evidence. *Transport Reviews,* Vol.33,No.3, 2013, pp.271-290.
9. Madre, J. L., Y.D. Bussière, R. Collet, and I.T. Villareal. *Are we heading towards a reversal of the trend for ever-greater mobility? Paper 2012-16*, International Transport Forum, OECD Publishing, 2012. http://www.internationaltransportforum.org/jtrc/DiscussionPapers/DP201216.pdf. Accessed April 2013.
10. Van Dender, K., and M. Clever. *New Recent Trends in Car Usage in Advanced Economies – Slower Growth Ahead? Paper No. 2013-0*9, International Transport Forum, OECD, 2013. http://www.internationaltransportforum.org/jtrc/DiscussionPapers/jtrcpapers.html . Accessed May 2013.
11. Litman, T. Changing travel demand: Implications for transport planning. *Institute of Transportation Engineers: ITE Journal,* Vol.76, No.9, 2006, pp.27-33.
12. American Planning Association (APA). *Investing in Place for Economic Growth and Competitiveness*. 2014. https://www.planning.org/newsreleases/2014/apr30.htm. Accessed June 2014.
13. Dutzik, T and Madsen, T. Frontier Group, and P. Baxandall, U.S. PIRG Education Fund. *A new way to go: The transportation apps and vehicle-sharing tools that are giving more Americans the Freedom to drive les*s. 2013. http://www.uspirg.org/reports/usp/new-way-go. Accessed July 014.
14. Crocco, F., L. Eboli, and G. Mazzulla. Individual attitudes and shopping mode characteristics affecting the use of e-shopping and related travel. *Transport and telecommunication*, Vol.14,No.1, 2013, pp.45-56.
15. Teeparthi, R. *Why Americans are driving less*? Graduate Thesis, Georgetown University, 2014. https://repository.library.georgetown.edu/handle/10822/709876. Accessed July 2, 2015.
16. Blumenberg, E., B.D. Taylor, M. Smart, K. Ralph, M. Wander and S. Brumbaugh. *What's Youth Got to Do with It? Exploring the Travel Behavior of Teens and Young Adults*. UCLA Institute of Transportation Studies, 2012. http://www.lewis.ucla.edu/publication/whats-youth-got-exploring-travel-behavior-teens-young-adults/. Accessed July 2015.
17. Kuhnimhof, T., M. Wirtz, and W. Manz. Decomposing Young Germans' Altered Car Use Patterns Lower Incomes, More Students, Decrease in Car Travel by Men, and More Multimodality. In *TRR: Journal of the TRB, No.2023*, TRB of the National Academies, Washington, D.C., 2012, pp.64-71.
18. Davis, B., T. Dutzik, Frontier Group, and P. Baxandall, U.S. PIRG Education Fund. *Transportation and the New Generation: Why young people are driving less and what it means for transportation policy*. 2012. http://www.frontiergroup.org/reports/fg/transportation-and-new-generation. Accessed April 2014.
19. Cervero, R., and K. Kockelman. Travel demand and the 3Ds: Density, diversity, and design. *Transportation Research D,* Vol.2, No.3, 1997, pp.199–219.
20. Ewing, R., and R. Cervero. Travel and the Built Environment: A Synthesis. In *TRR: Journal of the TRB, No.1780*, TRB of the National Academies, Washington, D.C., 2001, pp.87-114.
21. Ewing, R., and R. Cervero. Travel and the Built Environment: A Meta-Analysis. *Journal of the APA*, Vol.76,No.3, 2010, pp.266-294.
22. Ewing, R., K. Bartholomew, S. Winkelman, J.Walters, and D. Chen. *Growing Cooler: The Evidence on Urban Development and Climate Change.* Urban Land Institute, Washington, D.C., 2008.
23. Ewing, R., M.J. Greenwald, M. Zhang, J. Walters, M. Feldman, R. Cervero, and J. Thomas. *Measuring the impact of urban form and transit access on mixed use site trip generation rates—Portland pilot study*. U.S. Environmental Protection Agency, Washington, D.C., 2009.

24. Polzin, S.E., prepared for the USDOT. *The case for moderate growth in vehicle miles of travel: A critical juncture in U.S. travel behavior trends.* Center for Urban Transportation Research, University of South Florida, 2006.
25. TRB. *Special Report 298: Driving and the Built Environment: Effects of Compact Development on Motorized Travel, Energy Use, and CO2 Emissions.* TRB of the National Academies, Washington, D.C., 2009. http://www.trb.org/Publications/Blurbs/162093.aspx. Accessed May 2013.
26. Vernez-Moudon, A. and O. Stewart. *Tools for estimating VMT reductions from built environment changes, Report WA-RD 806.3*. Washington State DOT, 2013. http://www.wsdot.wa.gov/Research/Reports/800/806.3.htm. Accessed October 2013.
27. Cervero, R. and J. Murakami. Effects of built environments on vehicle miles traveled: evidence from 370 US urbanized areas. *Environment and Planning A,* Vol.42, No.2, 2010, pp.400-418.
28. Dulal, H.B., G. Brodnig, and C.G. Onoriose. Climate change mitigation in the transport sector through urban planning: A review. *Habitat International*, Vol.35, No.3, 2011, pp.494-500.
29. Handy, S. L. Urban Form and Pedestrian Choices: Study of Austin Neighborhoods. In *TRR: Journal of the TRB, No.1552*, TRB of the National Academies, Washington, D.C., 1996, pp.135-144.
30. Khattak, A.J., and D. Rodriguez, D. Travel behavior in neo-traditional neighborhood developments: A case study in USA. *Transportation Research A: Policy and Practice,* Vol.39, No.6, 2005, pp.481-500.
31. Badoe, D.A., and E.J. Miller. Transportation-land-use interaction: empirical findings in North America, and their implications for modeling. *Transportation Research D: Transport and Environment,* Vol.5, No.4, 2000, pp.235-263.
32. Schimek, P. Household motor vehicle ownership and use: How much does residential density matter? In *TRR: Journal of the TRB, No.1552*, TRB of the National Academies, Washington, D.C., 1996, pp.120-125.
33. Marshall, W.E. and N.W. Garrick. Effect of Street Network Design on Walking and Biking. In *TRR: Journal of the TRB, No.2198*, TRB of the National Academies, Washington, D.C., 2010, pp.103-115.
34. Holtzclaw, J.W. Smart growth – as seen from the air: Convenient neighborhood, skip the car. Air and Waste Management's 93rd Annual Meeting and Exhibition Proceedings, Sierra Club. vault.sierraclub.org/sprawl/transportation/holtzclaw-awma.pdf. Accessed July 2015.
35. Rentziou, A., K. Gkritza, and R.R. Souleyrette. VMT, energy consumption, and GHG emissions forecasting for passenger transportation. *Transportation Research A: Policy and Practice,* Vol. 46, No.3, 2012, pp.487-500.
36. Zimmerman, C. The life-cycle concept as a tool for travel research. *Transportation,* Vol.11, No.1, 1982, pp.51-69.
37. Bhat, C.R., and J.Y. Guo. A comprehensive analysis of built environment characteristics on household residential choice and auto ownership levels. *Transportation Research B: Methodological,* Vol.41, No.5, 2007, pp.506-526.
38. Weinberger, R., and F. Goetzke. Unpacking Preference: How Previous Experience Affects Auto Ownership in the United States. *Urban Studies,* Vol.47,No.10, 2010, pp. 2111-2128.
39. Banister, D. Influence of habit formation on modal choice – heuristic model. *Transportation,* Vol.7, No.1, 1978, pp.5-18.
40. Ewing, E., S. Hamidi, F. Gallivan, A.C.Nelson, and J.B. Grace. Structural equation models of VMT growth in US urbanised areas. *Urban Studies,*Vol.51, No.14, 2014, pp.3079-3096.
41. Dawkins, C.J. and A.C. Nelson. State growth management programs and central-city revitalization. *Journal of the APA*, Vol.69, No.4, 2003, pp.381-396.
42. Jaffe, E. *How Washington State Convinced Big Companies to Dramatically Reduce Drive-Alone Commutes: The state's Commute Trip Reduction program is a model for the nation.* The Atlantic

CityLab, 2015. http://www.citylab.com/cityfixer/2015/04/how-washington-state-convinced-big-companies-to-dramatically-reduce-drive-alone-commutes/389658/. Accessed July 2015.

43. Krueger, R. and D. Gibbs. 'Third Wave'' Sustainability? Smart Growth and Regional Development in the USA. *Regional Studies*, Vol.42, No.9, 2008, pp.1263-1274.
44. California Environmental Protection Agency Air Resources Board. *Sustainable Communities*. 2015. http://www.arb.ca.gov/cc/sb375/sb375.htm. Accessed July 2015.
45. Bordoff, J.E. and P.J. Noel. *Pay-as-you-drive auto insurance: A Simple way to reduce driving-related harms and increase equity*. The Hamilton Project, Brookings Institution, 2008. http://www.brookings.edu/research/papers/2008/07/payd-bordoffnoel. Accessed July 2015.
46. Newman, P., and J. Kenworthy. 'Peak Car Use': Understanding the Demise of Automobile Dependence. *World Transport, Policy & Practice,* Vol.17, No.2, 2011, pp.31-42.
47. Wilson, S.G., D.A. Plane, P.J. Mackun, T.R. Fischetti and J. Goworowska. *Patterns of metropolitan and micropolitan change: 2000 to 2010*. U.S. Census Bureau, 2012. http://www.census.gov/population/metro/data/c2010sr-01patterns.html. Accessed February 2013.
48. FHWA. *State Gasoline Tax Rates, 1982-1991, Table SS90-3.* Office of Highway Policy Information (OHPI), 1991. http://www.fhwa.dot.gov/policy/ohpi/hss/hsspubsarc.cfm. Accessed June 2015.
49. FHWA. *Table 8.2.3 State Motor-Fuel Tax Rates, 1997-2010.* OHPI, 2011. http://www.fhwa.dot.gov/policyinformation/statistics/2010/. Accessed July 2014.
50. U.S. Census Bureau. *Employment Status for Males and Females, State Level: 1990 (T26-T27); 2000 (T70-T71); 2008-2012 (T34-T35)*. New York City, NY: Social Explorer Dataset (SE), 2015. www.socialexplorer.com. Accessed June 2015.
51. U.S. Census Bureau. *Poverty Status of Families, State Level: 1990 (T92); 2000 (T179); 2008-2012 (T113).* New York City, NY: SE, 2015. www.socialexplorer.com. Accessed June 2015.
52. U.S. Census Bureau. *State population estimates: Annual time-series, 1990-1999. ST-99-3.* 1999. https://www.census.gov/popest/data/state/totals/1990s/tables/ST-99-03.txt. Accessed April 2012.
53. U.S. Census Bureau. *Annual estimates of population for U.S., Regions, States and Puerto Rico, 2000-2009. Table 1*. 2009. https://www.census.gov/popest/data/intercensal/state/state2010.html. Accessed April 2012.
54. U.S. Census Bureau. *Annual estimates of population for U.S., Regions, States and Puerto Rico, 2010-2011. Table 1*. 2011. https://www.census.gov/popest/data/historical/2010s/vintage_2011/state.html. Accessed April 2012.
55. U.S. Census Bureau. *Sex by Age, State Level: 1990 (T6- Decennial Census); 2000 (T6-Decennial Census); 2008-2012 (T-5 ACS 5-year estimates*). New York City, NY: SE, 2015. www.socialexplorer.com. Accessed June 2015.
56. FHWA. *Annual vehicle-miles of travel, by state and functional system, 1980-1995, Table VM-2*. 2011. http://www.fhwa.dot.gov/policy/ohpi/hss/hsspubsarc.cfm. Accessed April 2012.
57. FHWA. *Functional system travel, annual vehicle-miles, 1995-2011 Table VM-2*, 2014. http://www.fhwa.dot.gov/policyinformation/quickfinddata/qftravel.cfm. Accessed February 2014.
58. U.S. Bureau of Economic Analysis (BEA). *Gross Domestic Product (GDP) by State, All industry total, SIC, 1963-1997*. 2013. http://www.bea.gov/iTable/iTable.cfm?reqid=70&step=1&isuri=1&acrdn=1#reqid=70&step=1&isuri=1. Accessed May 2014.
59. U.S. BEA. *GDP by State, All industry total, NAICS, 1997-2012*. 2013. http://www.bea.gov/iTable/iTable.cfm?reqid=70&step=1&isuri=1&acrdn=1#reqid=70&step=1&isuri=1. Accessed March 2014.
60. U.S. Census Bureau. *Population Density Census,Tract Level: 1990 (T2); 2000 (T3); 2008-2012 (T2).* New York City, NY: SE, 2015. www.socialexplorer.com. Accessed February 2015.

61. U.S. Census Bureau. *Means of Transportation to Work, Tract Level: 1990 (T106); 2000 (T195); 2008-2012 (T128)*. New York City, NY: SE, 2015. www.socialexplorer.com. Accessed February 2015.

CONCLUSION

Since World War II, most of transportation policy in the U.S. has prioritized automobile travel, often to the detriment of other modes. Traffic congestion received the most attention of all automobile-related externalities and congestion-reduction measures became the primary driver of transportation system investments. These investments materialized themselves in the form of lane-capacity expansions to existing roadways as well as the introduction of new roads and highways. While temporarily relieving congestion, this approach became a cyclical pattern where capacity increases induced new travel and ultimately resulted in a return to a congested state. After decades of expensive highway system expansions, many states have realized the flaws of using an exclusively automobile-based planning approach to congestion relief and have adapted their methods incorporate a diversity of tools such as: expanded public transit; the introduction and promotion of rideshare programs; and initiating coordinated land use and transportation planning that enables trips by walking and biking and also serves to provide the critical mass necessary for sustaining transit operation.

Though the costs of highway improvements were often only considered from a "dollars-and-cents" perspective, the first part of this research provides an example of how sustainability concepts can be applied to measure automobile-oriented transportation systems. In doing so, it was determined that beyond economic considerations, the societal and environmental costs of car-centric systems are high. Governments in the U.S. are charged with protecting and promoting the health, safety and general welfare of their constituents. States that continue to force residents to rely on private automobile trips to meet day-to-day needs (a "prosthetic device" as referred to by Jeff Speck, author of "Walkable City") are ultimately exposing residents to a higher risk of automobile accident-related fatalities. In addition, higher driving also equates to higher greenhouse gas (GHG) emissions levels which, in accelerating global warming, are expected to affect the livelihoods and safety of residents across the U.S. While federal policymakers have failed to take definitive actions to reduce GHG emissions, many states have been leaders in acknowledging and taking steps to reduce the anthropogenic causes of global warming. Since a transportation sector that is focused on single-occupancy vehicles generates high GHG emissions, many state and local governments have sought to reduce VMT in order to reduce GHG emissions. As we have now entered the peak car travel era, it appears that these state, metropolitan and local initiatives have been successful at reducing car travel.

Though peak car travel is partly a byproduct of socioeconomic changes, it is also the result of deliberate actions at various scales of government. Some of these actions have been motivated climate change concerns or by continued attempts to relieve traffic congestion while others have been based in economic goals of protecting productive farm and forestland or promoting efficient and fiscally-sound public infrastructure improvements. Regardless of the motivations behind these policies or the means to achieving these goals, these actions have served to reduce driving levels in one way or another. Considering the high costs associated with driving, these VMT-reduction strategies have shown promising results.

For decades, economic growth and increases in driving occurred concurrently with increased wealth and an expanded workforce spurring increased car ownership and driving. In a nation where manufacturing and construction drove the economy for so long, the thought that promoting car travel would stimulate the economy through road construction and automobile manufacturing seemed reasonable. In the modern global economy, however, household income in small-town America may be more affected by decisions made on another continent than by the decisions made in their own state or town. In addition, relying on a mode of travel that depends on imported fossil fuels subjects American households to the volatility of international markets and gas price fluctuations. While U.S. cities and states struggle to compete for economic development nationally and globally, U.S. governments may be better served to shift some of their focus towards affecting the costs borne by households within their jurisdictions. With transportation representing a significant share of household budgets (both through direct costs and indirectly through taxes), governments should work towards providing an integrated land use and transportation system that relieves some of the cost burdens on households and minimizes their vulnerability to external forces. The fact that there has been a widespread shift to non-car modes in high density areas during economically-challenging times shows that, when a diversified transportation system is present, people will choose to switch modes in order to access the same activities. The justification for most government investments in transportation infrastructure is the fact that transportation systems are the spine of our economic systems. As a result, policymakers owe it to their constituents to support land use and transportation systems that are the most efficient and effective in moving goods and people through space. While automobiles may provide a user with more freedom then in other modes in certain circumstances, car travel also comes at a great expense to taxpayers, commuters and businesses. These circumstances where car travel is most convenient are typically a product of heavy non-user subsidies that prioritize car travel to start with and do not provide an adequate opportunity (whether through funding or design) for non-car modes to compete.

Though the nature of the relationship between vehicle travel and the economy is still up for debate, peak car travel is a new era of travel and therefore policy and planning decisions need to be made within this context. States that continue to prioritize car-dependent transportation systems do so at a high cost. This business-as-usual mentality will either facilitate out-migration of residents fed up with increasing tax burdens and decreasing quality of life or, hopefully sooner rather than later, bring leaders to the realization that a VMT-based predict-and-provide approach to transportation planning is a ultimately a losing and costly endeavor. Luckily, this paradigm shift has already occurred in several states while others are starting to follow suit. In time, transportation systems will be measured not by the amount of miles driven but by the access that the system provides in enabling people of all ages, abilities and income levels to reach desired locations in a convenient, safe and comfortable manner. To do so automobile travel should no longer continue to be exclusively promoted but it should not be ostracized either. Instead, automobile travel needs to be a complementary part of a comprehensive and coordinated transportation and land use system.

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